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(12) **United States Patent**
Baker

(10) **Patent No.: US 11,200,983 B2**
(45) **Date of Patent: *Dec. 14, 2021**

(54) **PATHWAY PLANNING SYSTEM AND METHOD**

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(73) Assignee: **COVIDIEN LP**, Mansfield, MA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 1020 days.

This patent is subject to a terminal disclaimer.

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(22) Filed: **Feb. 17, 2017**

(65) **Prior Publication Data**

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Related U.S. Application Data

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(51) **Int. Cl.**
G06F 3/048 (2013.01)
G16H 50/50 (2018.01)
(Continued)

(52) **U.S. Cl.**
CPC ***G16H 50/50*** (2018.01); ***G06F 3/0482*** (2013.01); ***G06F 3/04845*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC G06T 19/00; G06T 15/08; G06T 17/00; G06F 19/321; G06F 16/5854; G16H 40/63
See application file for complete search history.

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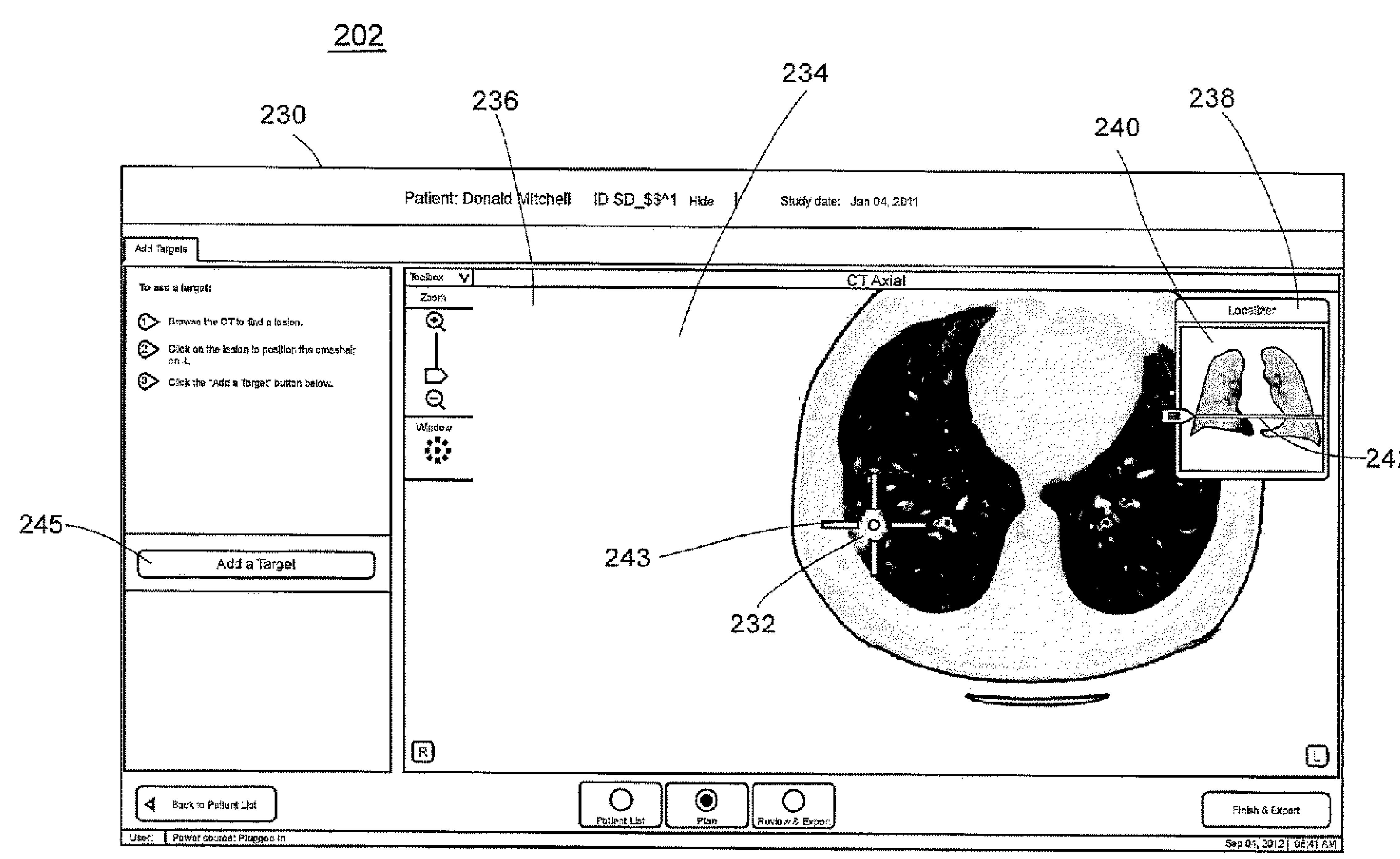
Primary Examiner — William C Trapanese
(74) *Attorney, Agent, or Firm* — Weber Rosselli & Cannon LLP

(57) **ABSTRACT**

A system and method for planning a pathway through an anatomical luminal network of a patient including a computing device having at least one processor; a display device in communication with the computing device; and a user interface configured for display on the display device and configured to guide a user through a pathway planning procedure. The user interface includes a patient selection window configured to receive a user input to select a patient having CT image data on which to perform pathway planning; a target selection window configured to receive a user input to select at least one target from the CT image data; and an airway finder window configured to generate at least one pathway from the at least one target to an entry point of the anatomical luminal network in response to a user input.

20 Claims, 23 Drawing Sheets



(51) **Int. Cl.**

G16H 40/63	(2018.01)
G06F 3/0482	(2013.01)
G06F 3/0484	(2013.01)
G06T 15/08	(2011.01)
G06T 19/00	(2011.01)

(52) **U.S. Cl.**
CPC ***G06T 15/08*** (2013.01); ***G06T 19/003*** (2013.01); ***G16H 40/63*** (2018.01); *G06T 2200/24* (2013.01); *G06T 2210/41* (2013.01)

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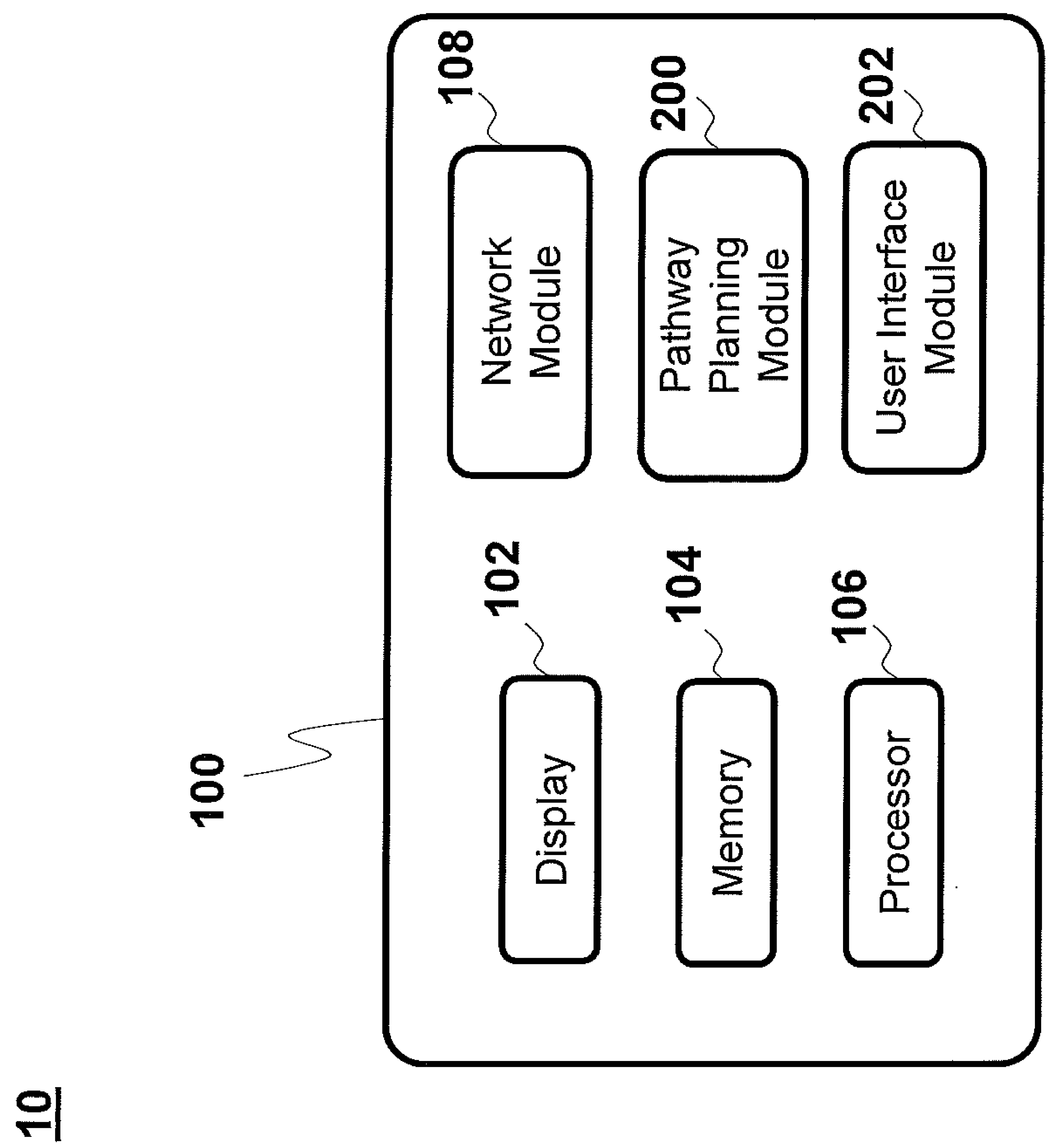
10
100
Display
102
Memory
104
Processor
106
Network Module
108
Pathway Planning Module
200
User Interface Module
202

FIG. 1

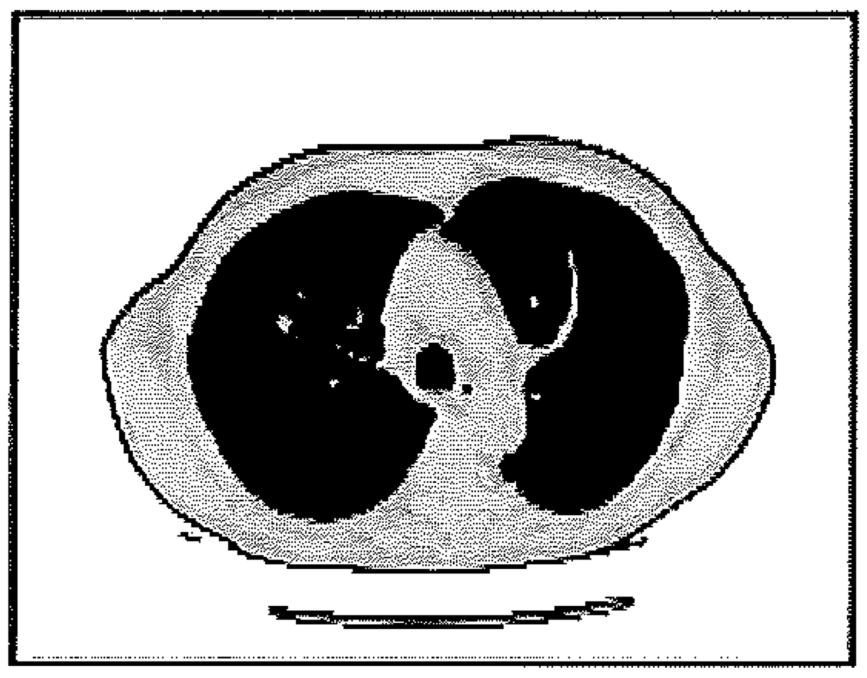

FIG. 2A

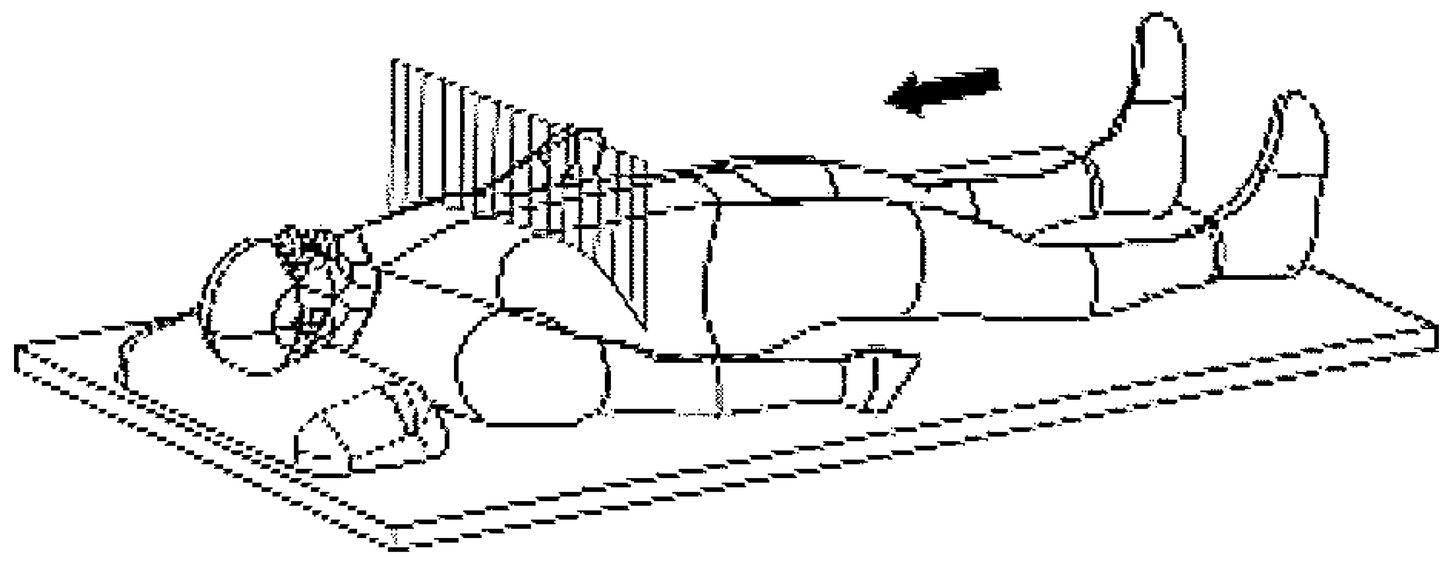

FIG. 2B

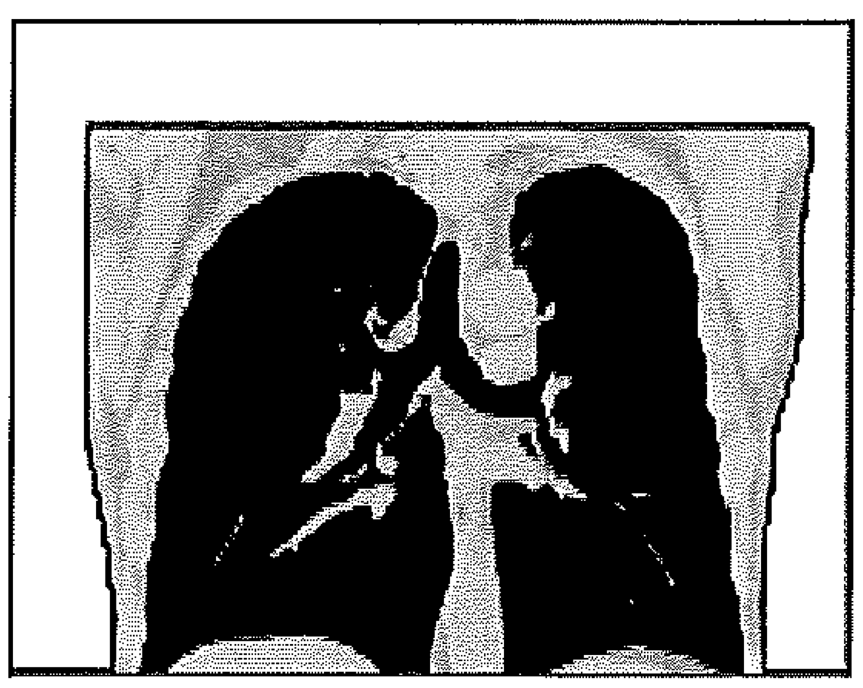

FIG. 2C

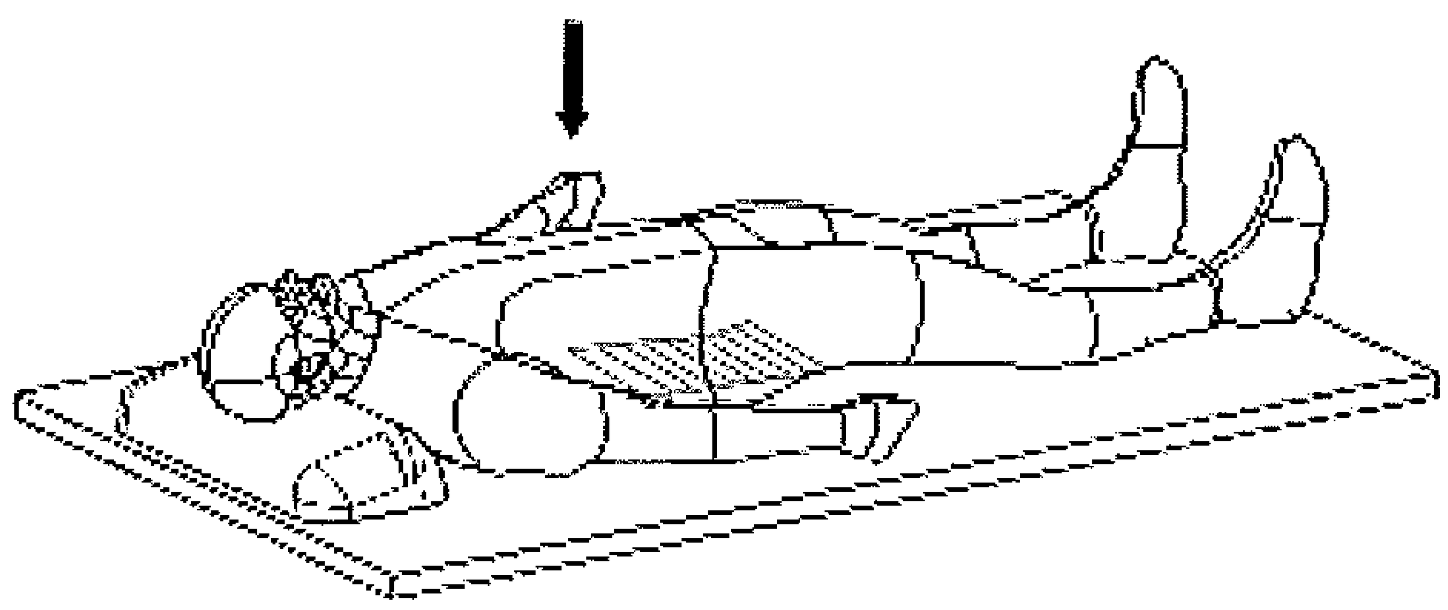

FIG. 2D

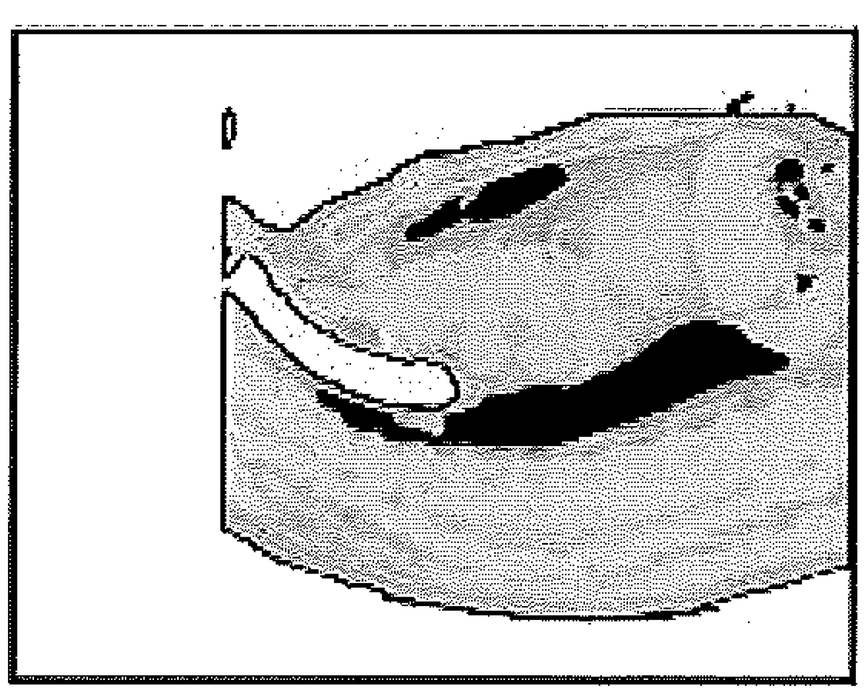

FIG. 2E

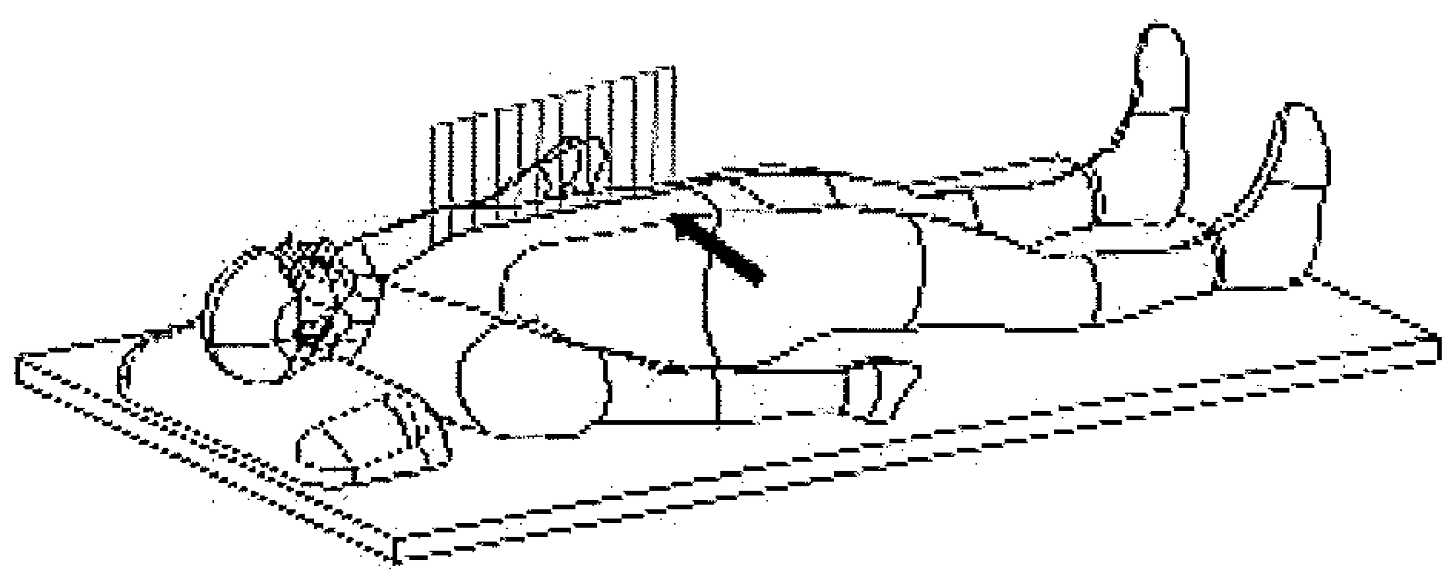

FIG. 2F

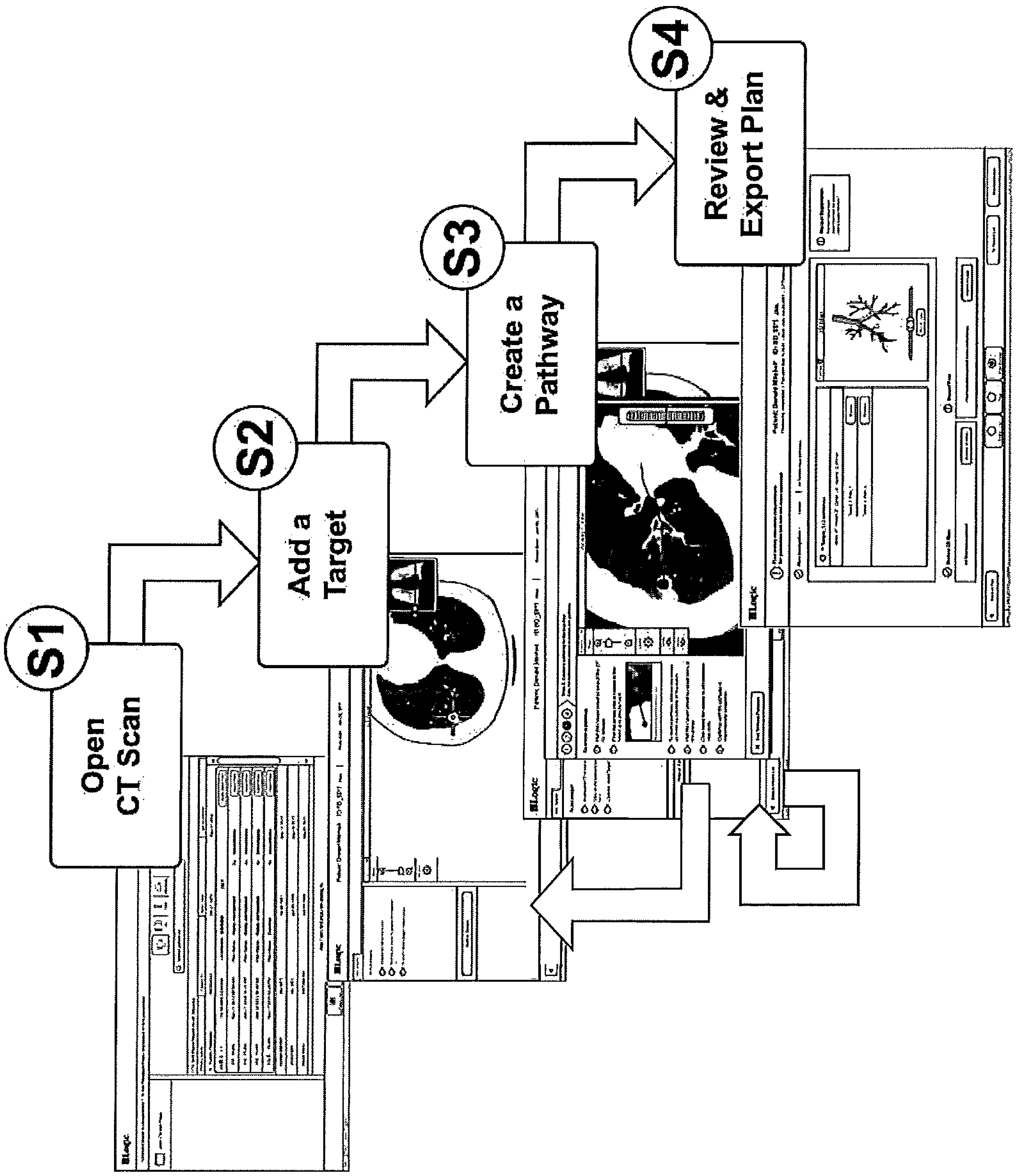
S1
Open CT Scan
S2
Add a Target
S3
Create a Pathway
S4
Review & Export Plan

FIG. 3

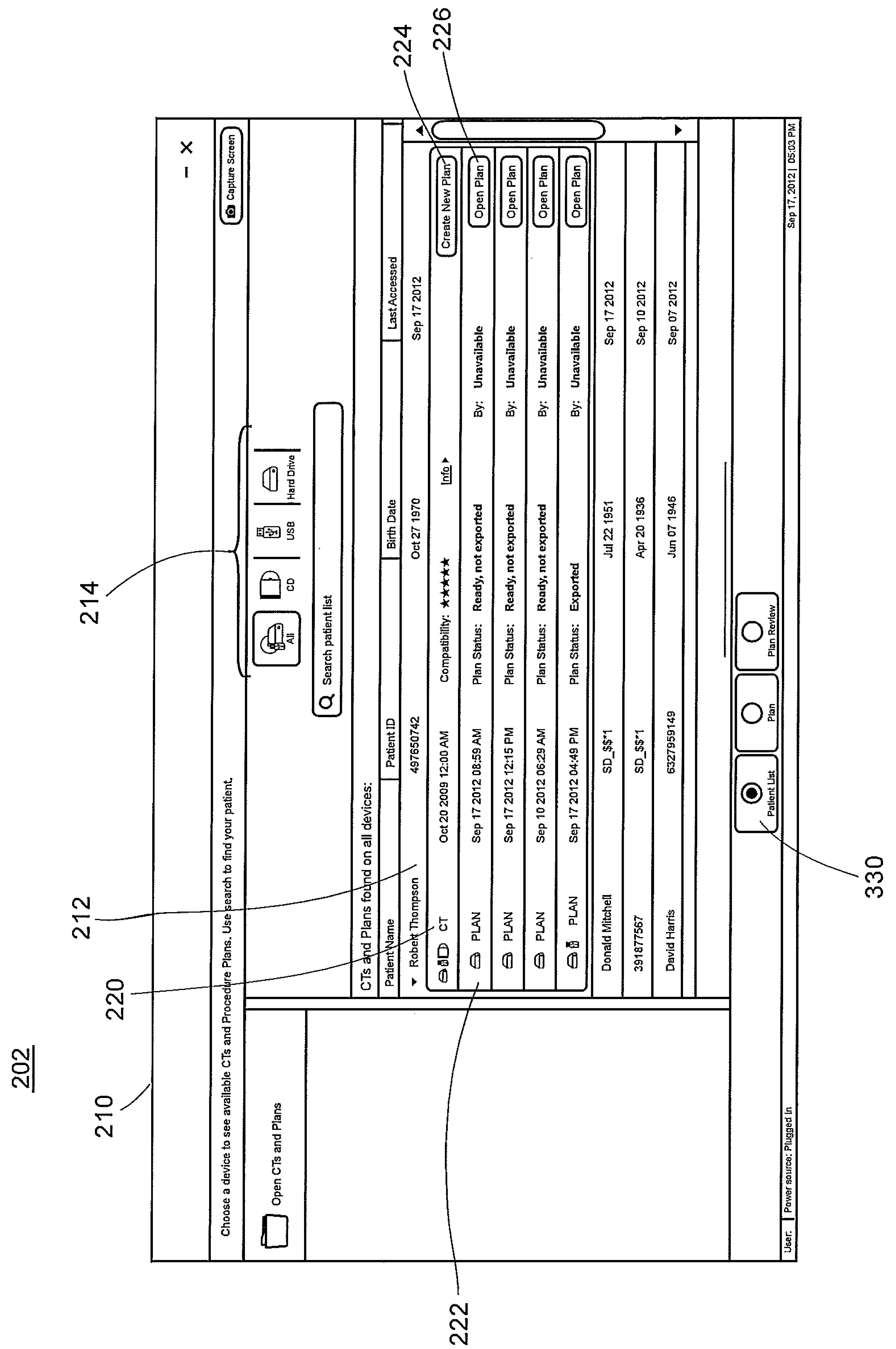
202
210
212
214
220
222
224
226
330
Choose a device to see available CTs and Procedure Plans. Use search to find your patient.
Capture Screen
Open CTs and Plans
All
CD
USB
Hard Drive
Search patient list
CTs and Plans found on all devices:
Patient Name
Patient ID
Birth Date
Last Accessed
Robert Thompson
497650742
Oct 27 1970
Sep 17 2012
CT
Oct 20 2009 12:00 AM
Compatibility: ★★★★★
Info
Create New Plan
PLAN
Sep 17 2012 08:59 AM
Plan Status: Ready, not exported
By: Unavailable
Open Plan
PLAN
Sep 17 2012 12:15 PM
Plan Status: Ready, not exported
By: Unavailable
Open Plan
PLAN
Sep 10 2012 06:29 AM
Plan Status: Ready, not exported
By: Unavailable
Open Plan
PLAN
Sep 17 2012 04:49 PM
Plan Status: Exported
By: Unavailable
Open Plan
Donald Mitchell
SD_$$*1
Jul 22 1951
Sep 17 2012
391877567
SD_$$*1
Apr 20 1936
Sep 10 2012
David Harris
6327959149
Jun 07 1946
Sep 07 2012
Patient List
Plan
Plan Review
User:
Power source: Plugged in
Sep 17, 2012 | 05:03 PM

FIG. 4

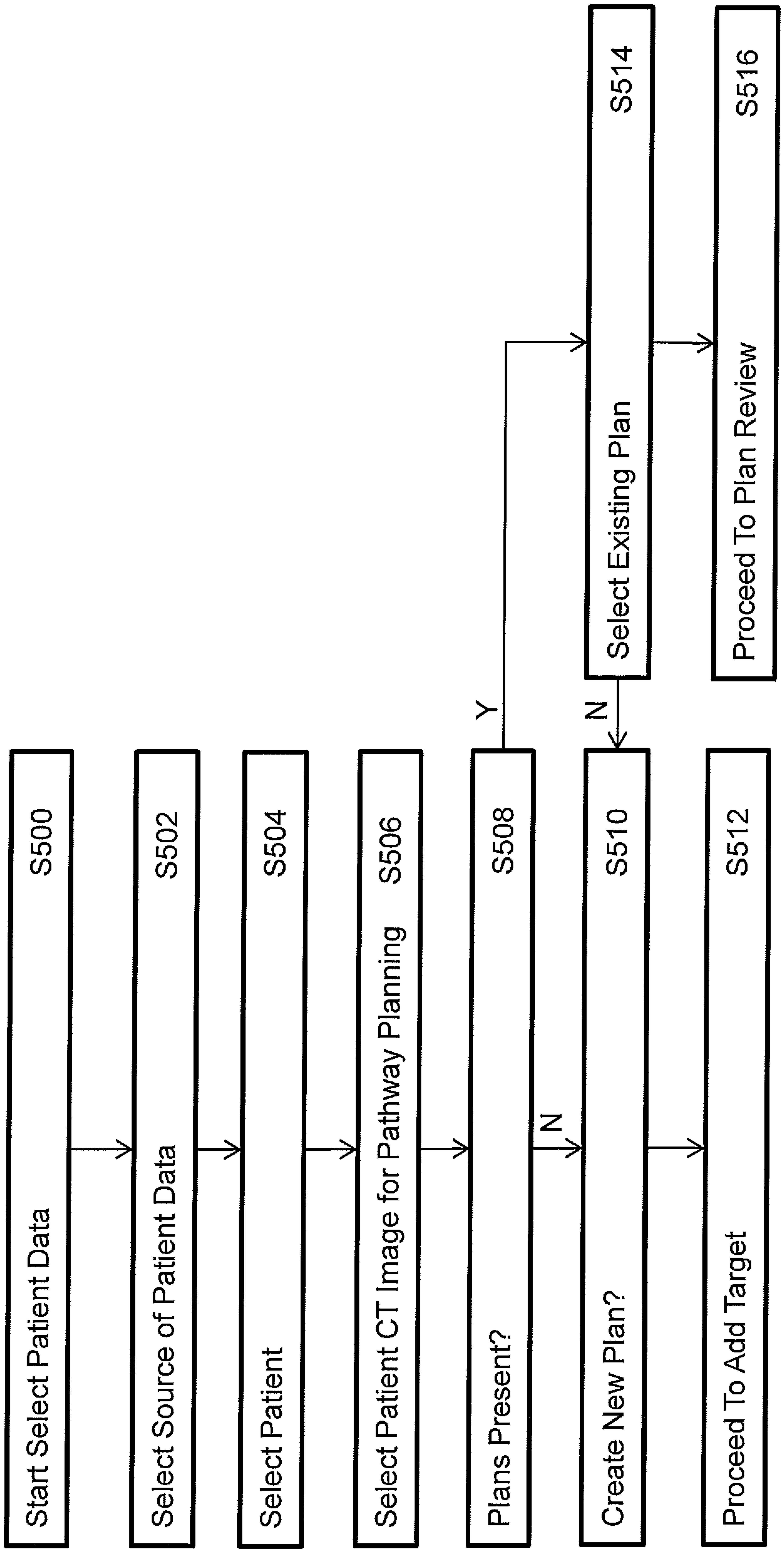
Start Select Patient Data
S500
Select Source of Patient Data
S502
Select Patient
S504
Select Patient CT Image for Pathway Planning
S506
Plans Present?
S508
Y
N
Create New Plan?
S510
N
Proceed To Add Target
S512
Select Existing Plan
S514
Proceed To Plan Review
S516

FIG. 5

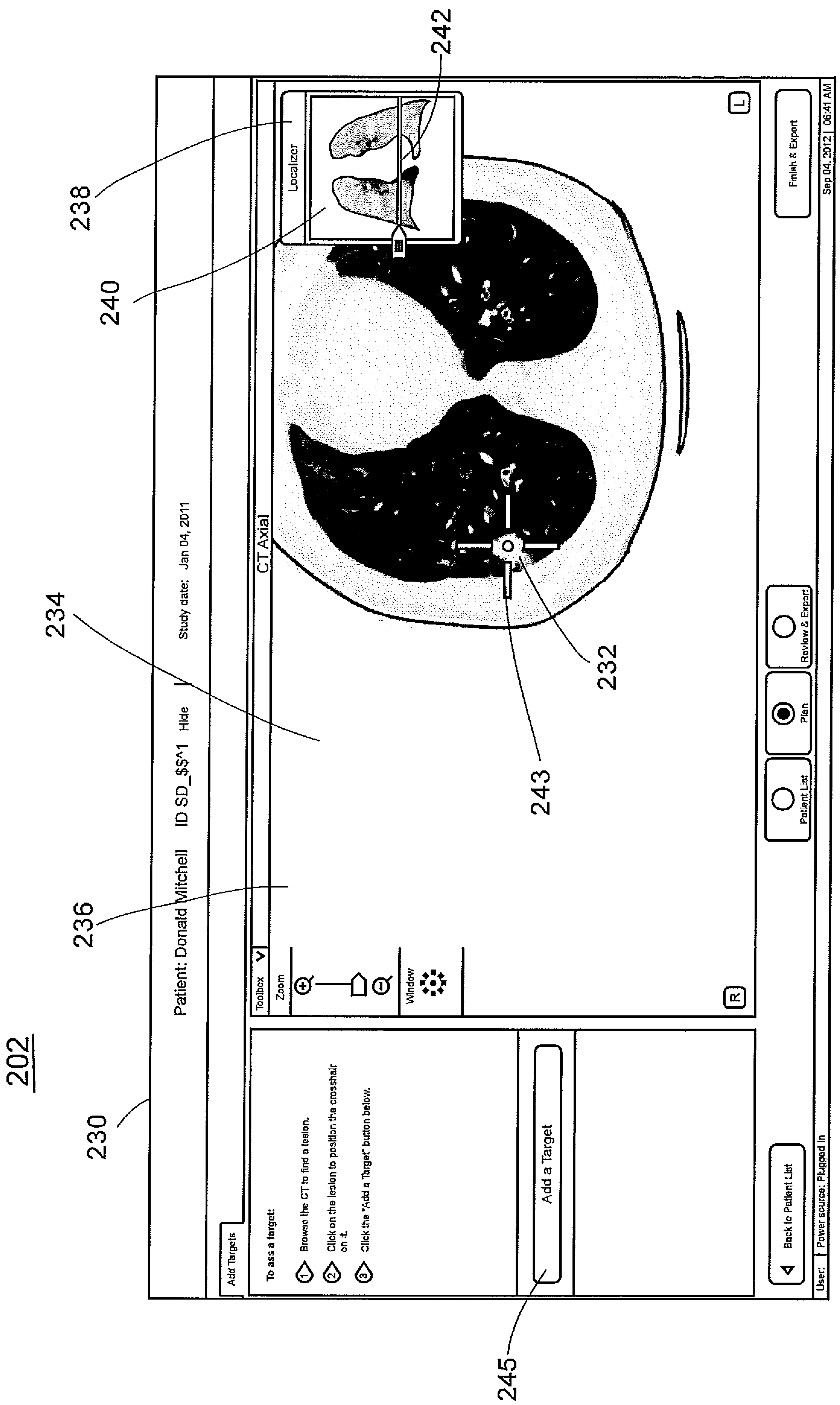
202
230
234
236
238
240
242
243
232
245
Patient: Donald Mitchell
ID SD_$$^1
Hide
Study date: Jan 04, 2011
Add Targets
To ass a target:
Browse the CT to find a lesion.
Click on the lesion to position the crosshair on it.
Click the "Add a Target" button below.
Add a Target
Toolbox
Zoom
Window
CT Axial
Localizer
Patient List
Plan
Review & Export
Finish & Export
Back to Patient List
User:
Power source: Plugged In
Sep 04, 2012 | 06:41 AM

FIG. 6

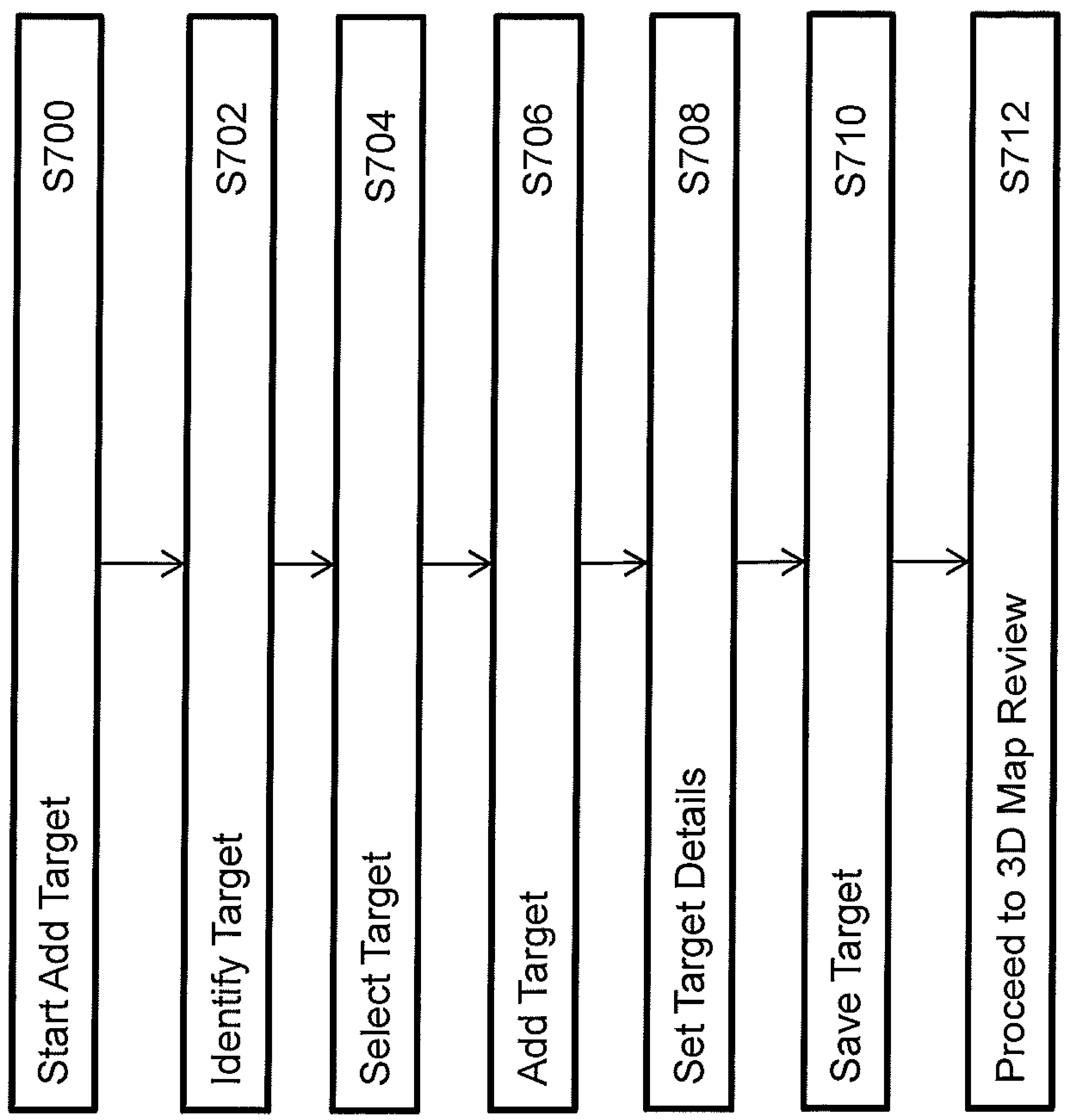
Start Add Target
S700
Identify Target
S702
Select Target
S704
Add Target
S706
Set Target Details
S708
Save Target
S710
Proceed to 3D Map Review
S712

FIG. 7

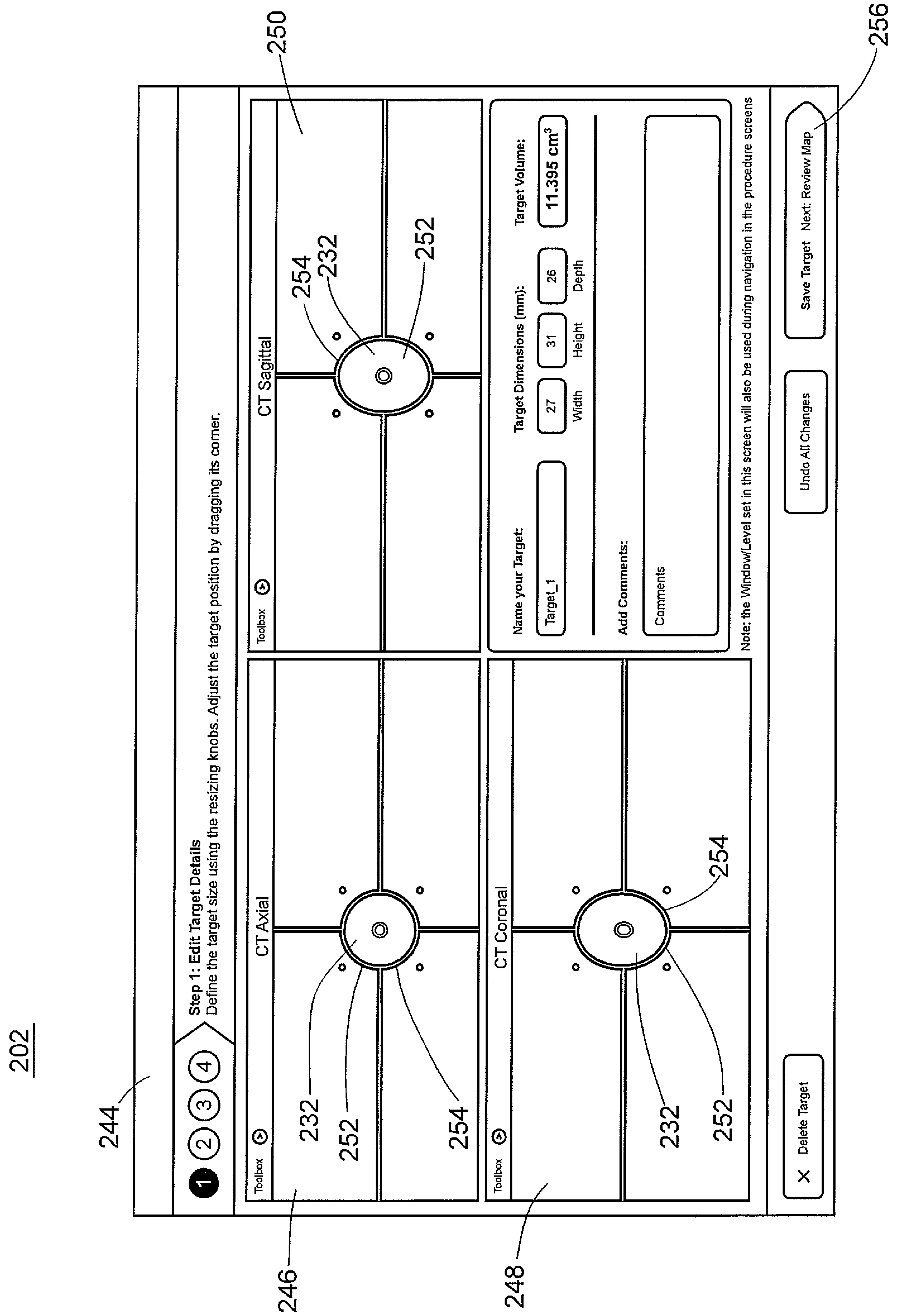
202
244
246
248
250
256
232
252
254
Step 1: Edit Target Details
Define the target size using the resizing knobs. Adjust the target position by dragging its corner.
1 2 3 4
Toolbox
CT Axial
CT Coronal
CT Sagittal
Name your Target:
Target_1
Target Dimensions (mm):
27 31 26
Width Height Depth
Target Volume:
11.395 cm³
Add Comments:
Comments
Note: the Window/Level set in this screen will also be used during navigation in the procedure screens
Delete Target
Undo All Changes
Save Target Next: Review Map

FIG. 8

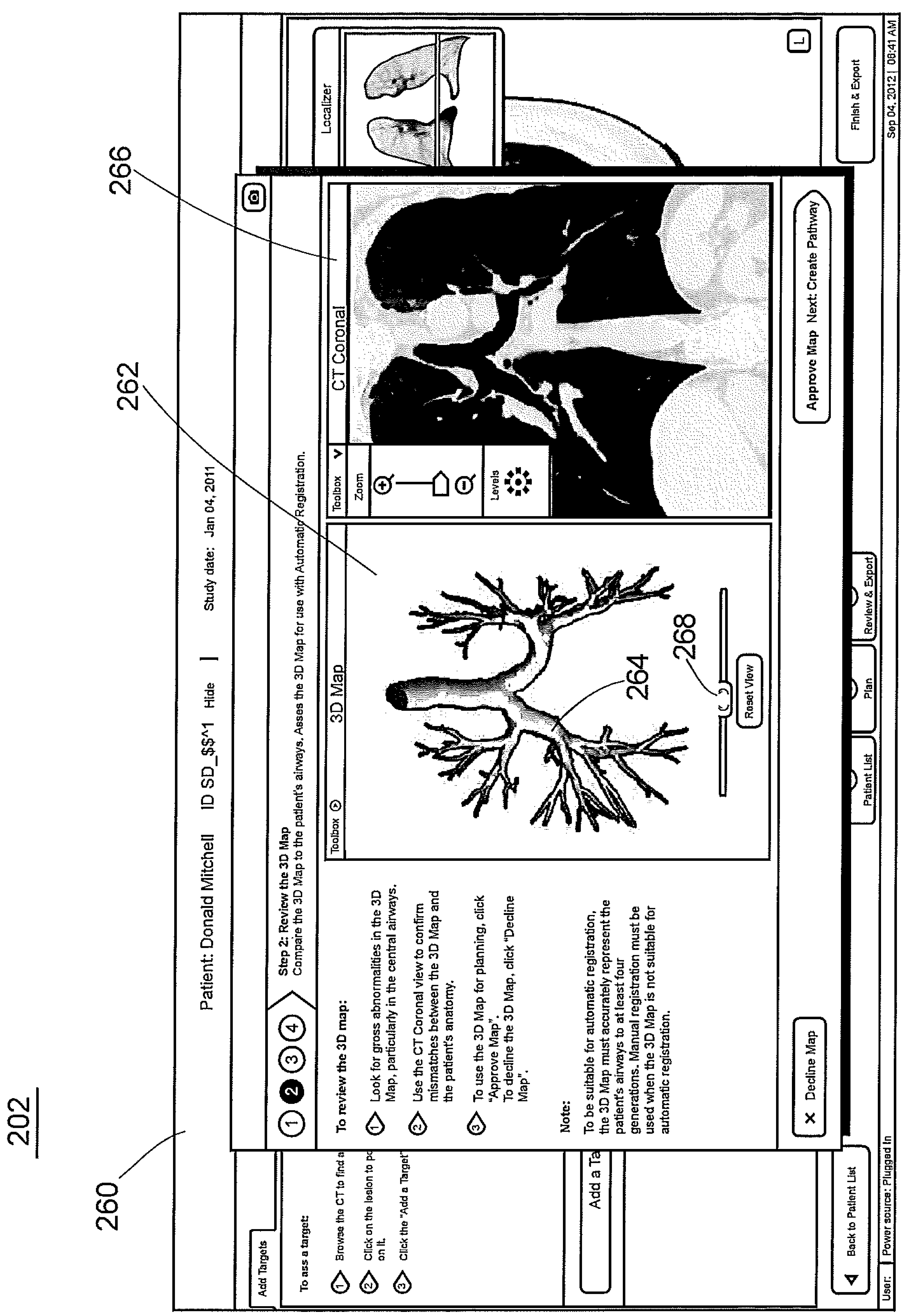
202
260
262
264
266
268
Patient: Donald Mitchell ID SD_$$^1 Hide Study date: Jan 04, 2011
Step 2: Review the 3D Map
Compare the 3D Map to the patient's airways. Asses the 3D Map for use with Automatic Registration.
To review the 3D map:
Look for gross abnormalities in the 3D Map, particularly in the central airways.
Use the CT Coronal view to confirm mismatches between the 3D Map and the patient's anatomy.
To use the 3D Map for planning, click "Approve Map". To decline the 3D Map, click "Decline Map".
Note:
To be suitable for automatic registration, the 3D Map must accurately represent the patient's airways to at least four generations. Manual registration must be used when the 3D Map is not suitable for automatic registration.
Toolbox
3D Map
CT Coronal
Zoom
Levels
Reset View
Localizer
Decline Map
Approve Map Next: Create Pathway
Add Targets
To ass a target:
Add a Ta
Back to Patient List
Patient List
Plan
Review & Export
Finish & Export
User: Power source: Plugged In
Sep 04, 2012 | 08:41 AM

FIG. 9

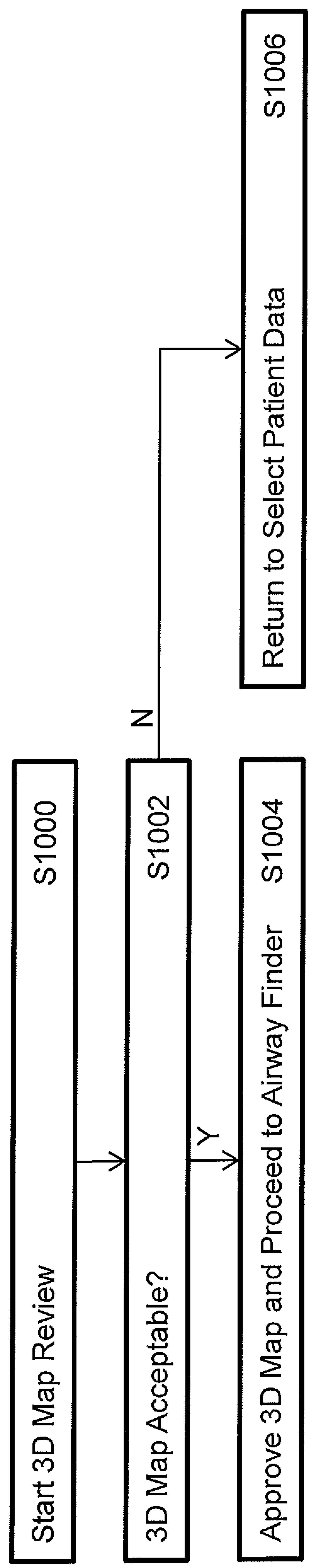
Start 3D Map Review
S1000
3D Map Acceptable?
S1002
Y
N
Approve 3D Map and Proceed to Airway Finder
S1004
Return to Select Patient Data
S1006

FIG. 10

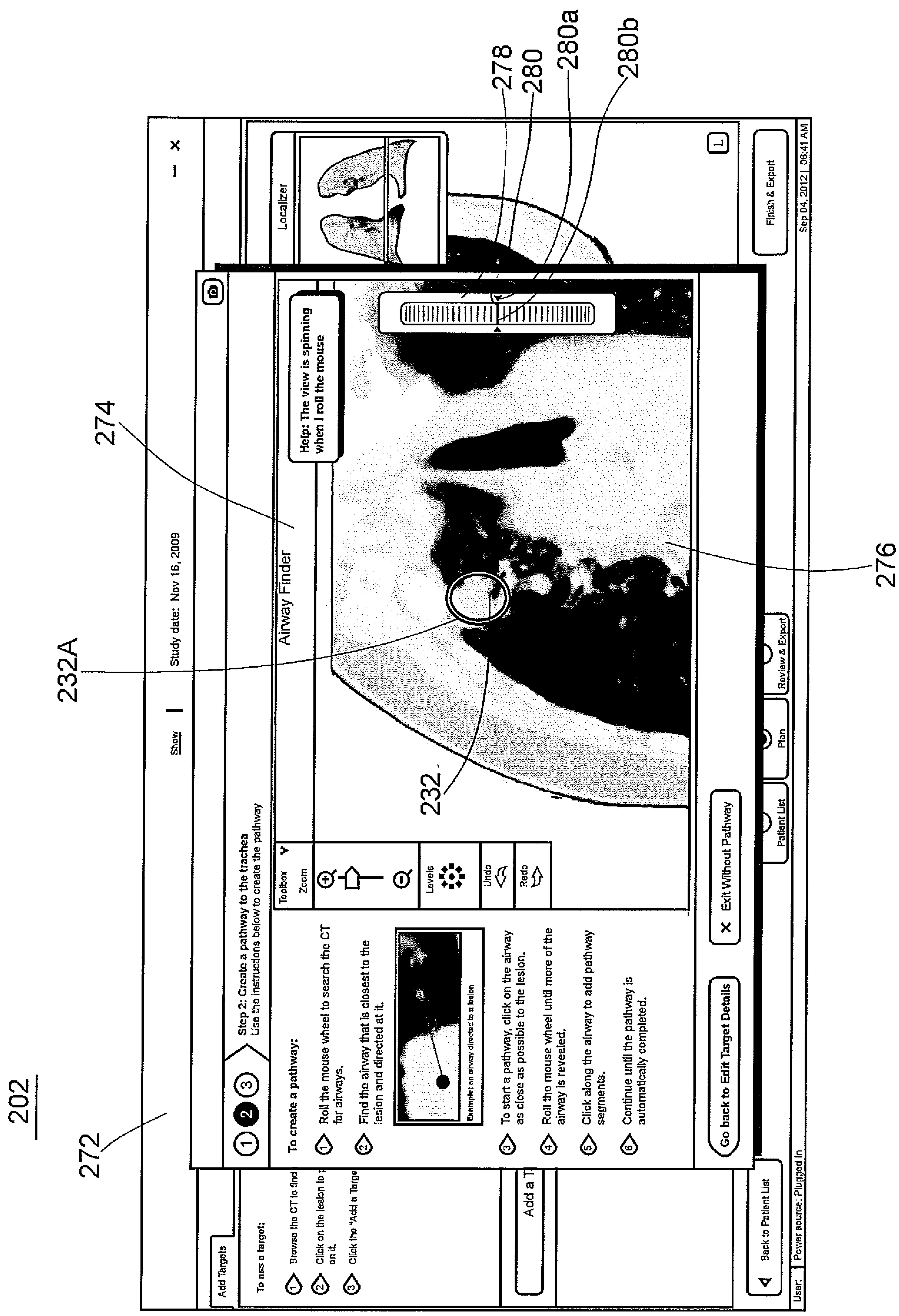
202
272
274
276
278
280
280a
280b
232A
232
Study date: Nov 16, 2009
Airway Finder
Help: The view is spinning when I roll the mouse
Localizer
Finish & Export
Step 2: Create a pathway to the trachea
Use the instructions below to create the pathway
To create a pathway:
Roll the mouse wheel to search the CT for airways.
Find the airway that is closest to the lesion and directed at it.
To start a pathway, click on the airway as close as possible to the lesion.
Roll the mouse wheel until more of the airway is revealed.
Click along the airway to add pathway segments.
Continue until the pathway is automatically completed.
Toolbox
Zoom
Levels
Undo
Redo
Go back to Edit Target Details
Exit Without Pathway
Patient List
Plan
Review & Export
Add Targets
Back to Patient List
Power source: Plugged In
Sep 04, 2012 | 06:41 AM

FIG. 11A

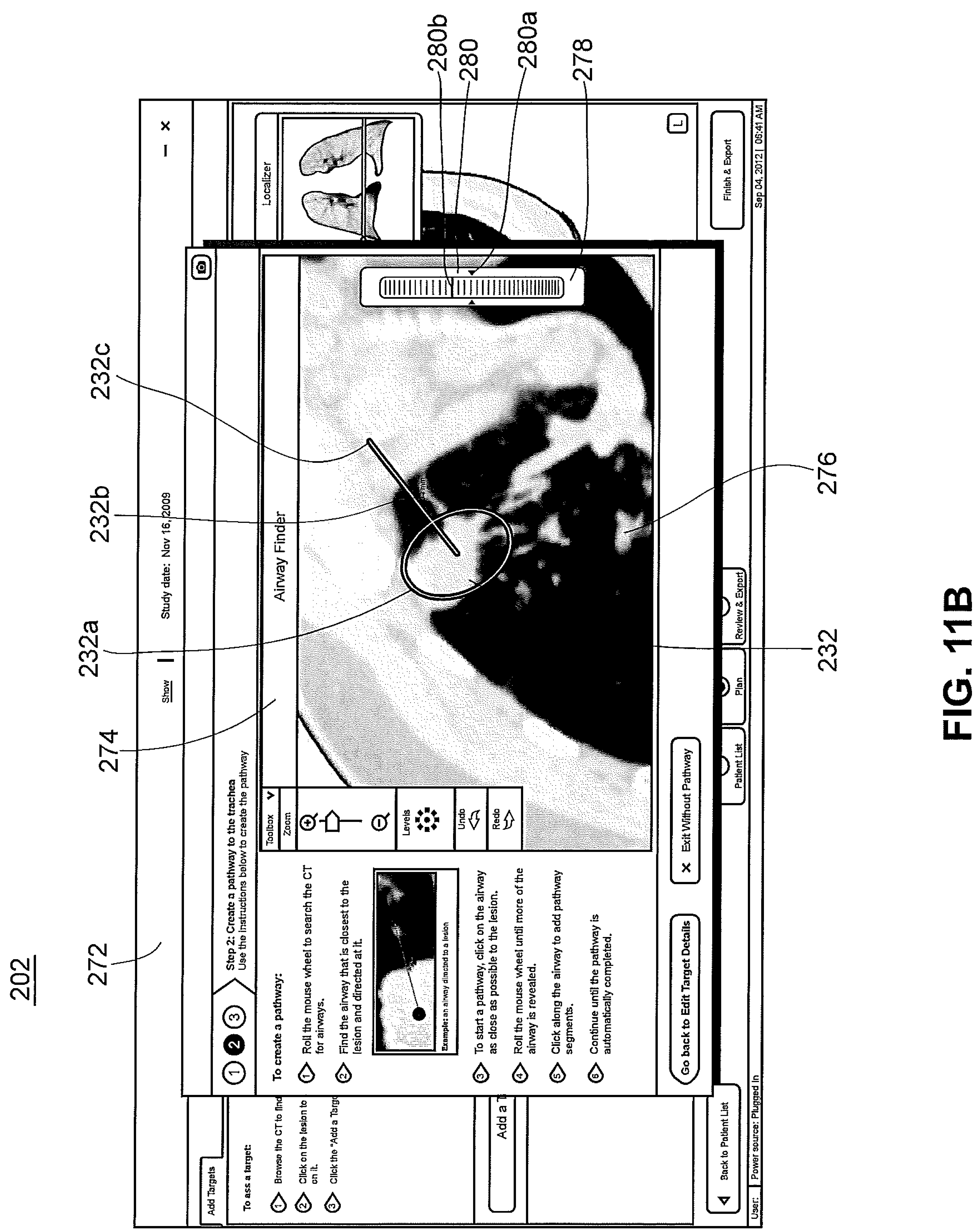
202
272
274
232a
232b
232c
276
232
278
280a
280
280b
Airway Finder
Study date: Nov 16, 2009
Step 2: Create a pathway to the trachea
Use the instructions below to create the pathway
To create a pathway:
Go back to Edit Target Details
Exit Without Pathway
Finish & Export
Localizer

FIG. 11B

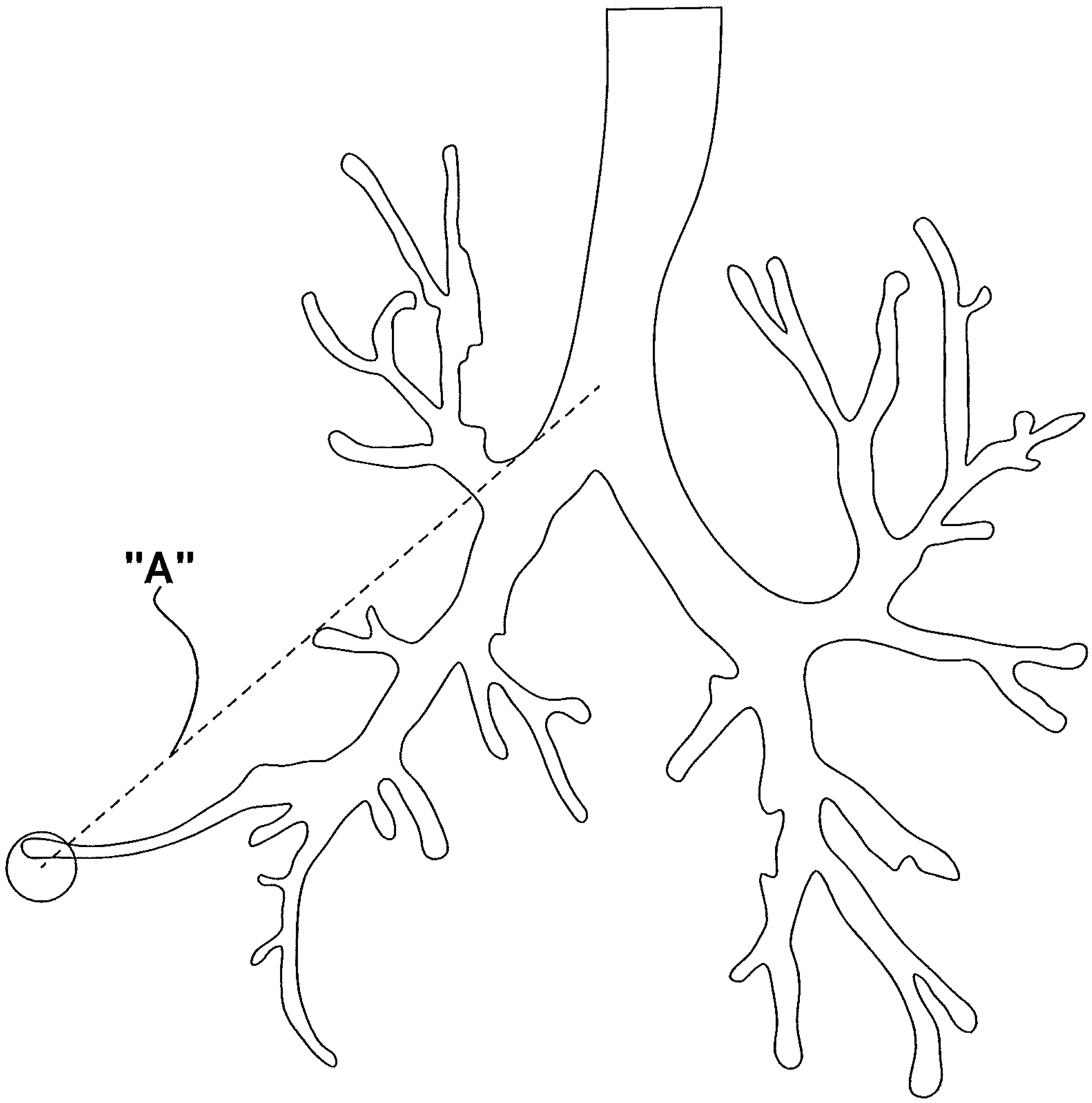

FIG.11C

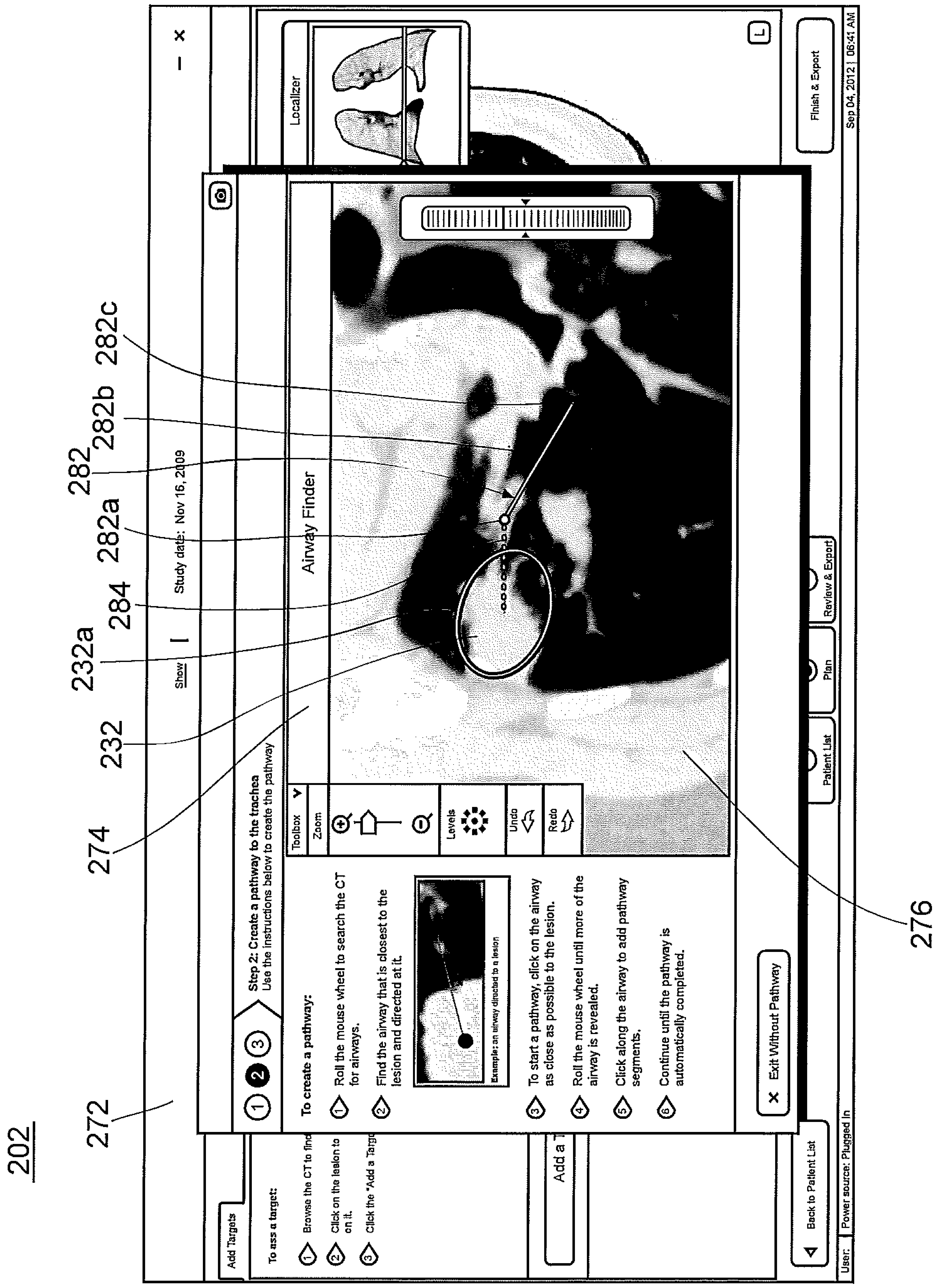
202
272
274
232
232a
284
282a
282
282b
282c
276
Airway Finder
Step 2: Create a pathway to the trachea
Use the instructions below to create the pathway
To create a pathway:
Roll the mouse wheel to search the CT for airways.
Find the airway that is closest to the lesion and directed at it.
To start a pathway, click on the airway as close as possible to the lesion.
Roll the mouse wheel until more of the airway is revealed.
Click along the airway to add pathway segments.
Continue until the pathway is automatically completed.
Exit Without Pathway
Study date: Nov 16, 2009
Localizer
Finish & Export
Review & Export
Plan
Patient List
Back to Patient List

FIG. 11D

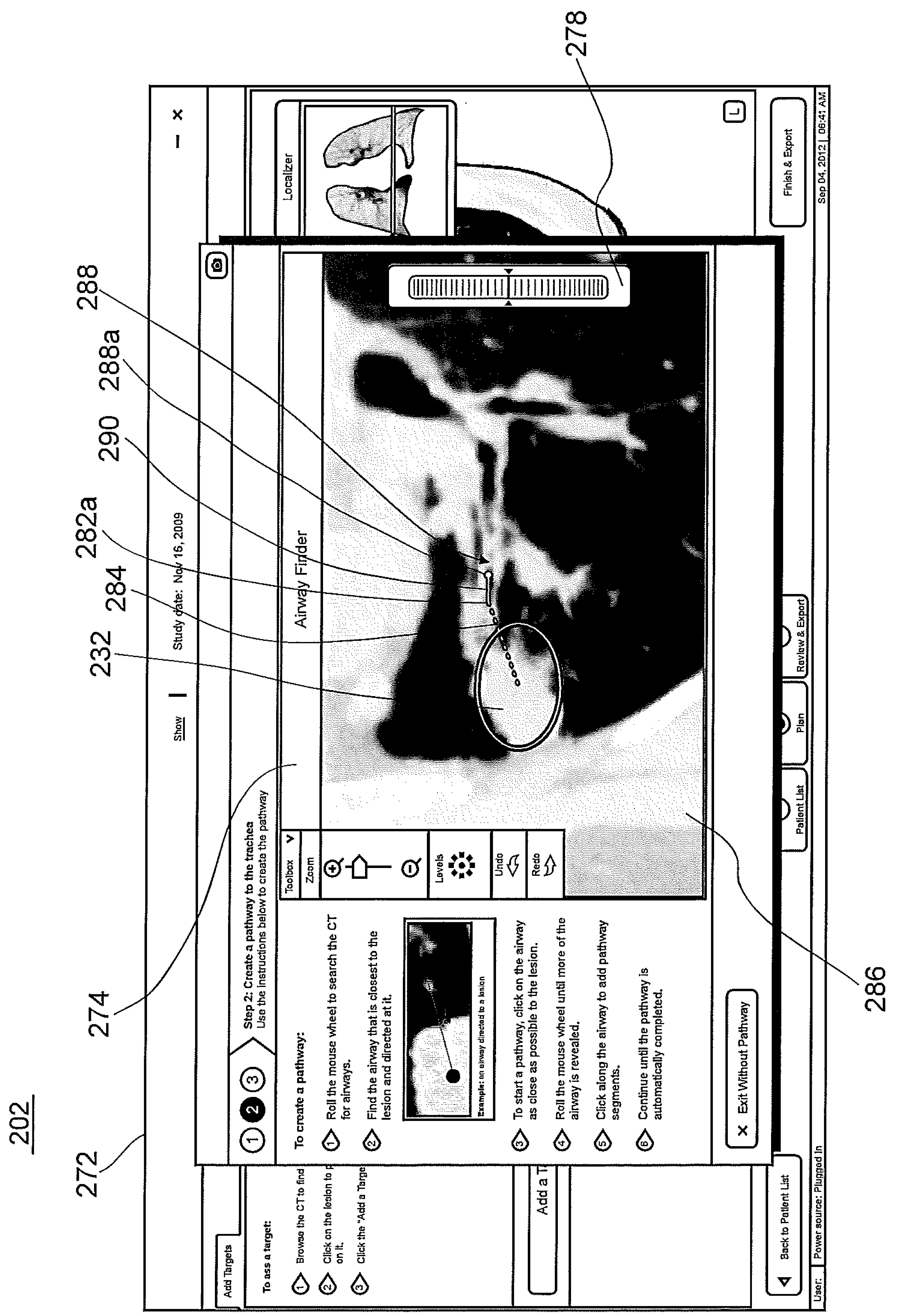

FIG. 11E

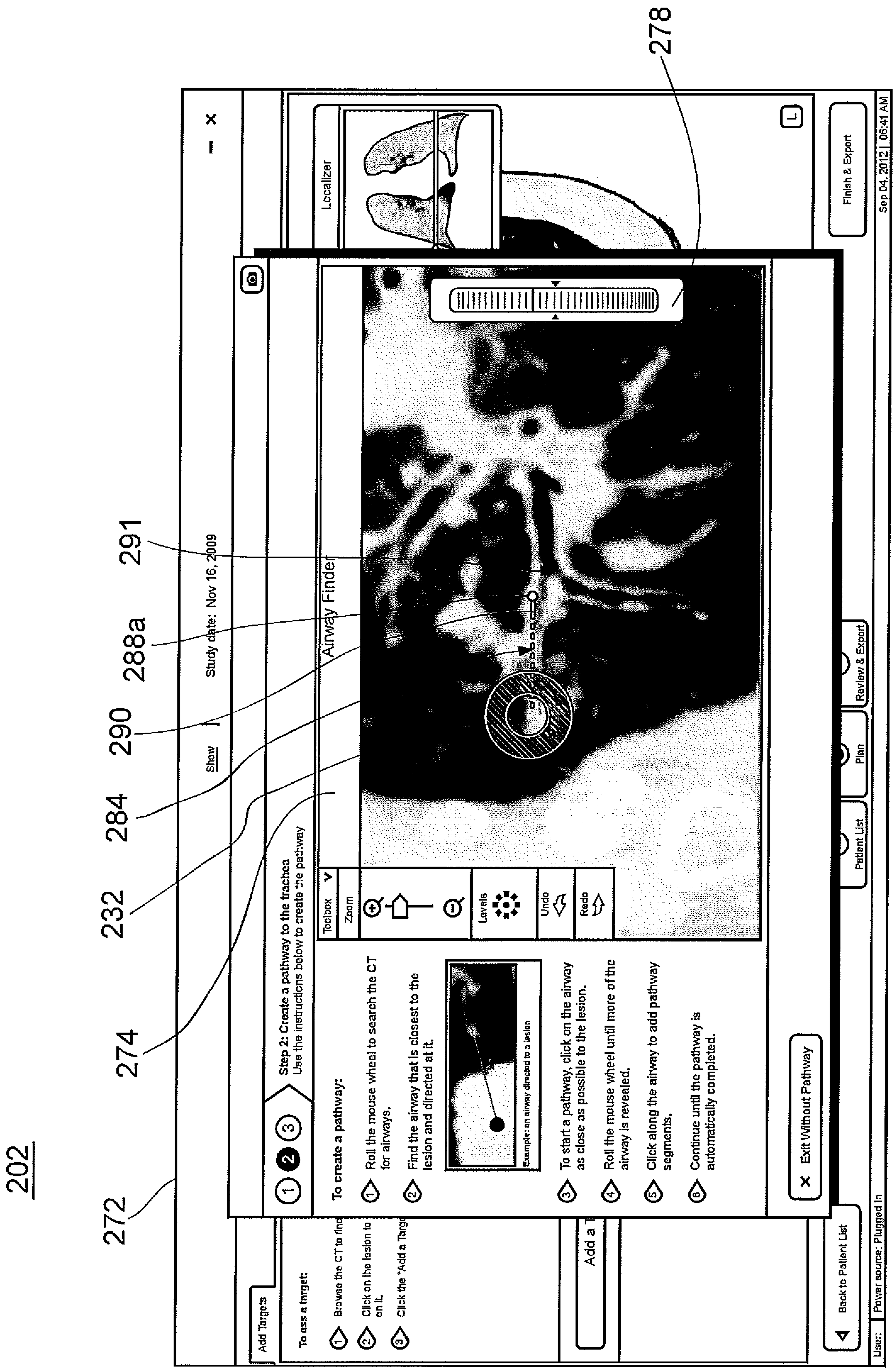
202
272
274
232
284
290
288a
291
278
Study date: Nov 16, 2009
Airway Finder
Step 2: Create a pathway to the trachea
Use the instructions below to create the pathway
To create a pathway:
Roll the mouse wheel to search the CT for airways.
Find the airway that is closest to the lesion and directed at it.
To start a pathway, click on the airway as close as possible to the lesion.
Roll the mouse wheel until more of the airway is revealed.
Click along the airway to add pathway segments.
Continue until the pathway is automatically completed.
Exit Without Pathway
Toolbox
Zoom
Levels
Undo
Redo
Localizer
Finish & Export
Patient List
Plan
Review & Export
Back to Patient List
Add Targets
Power source: Plugged In
Sep 04, 2012 | 06:41 AM

FIG. 11F

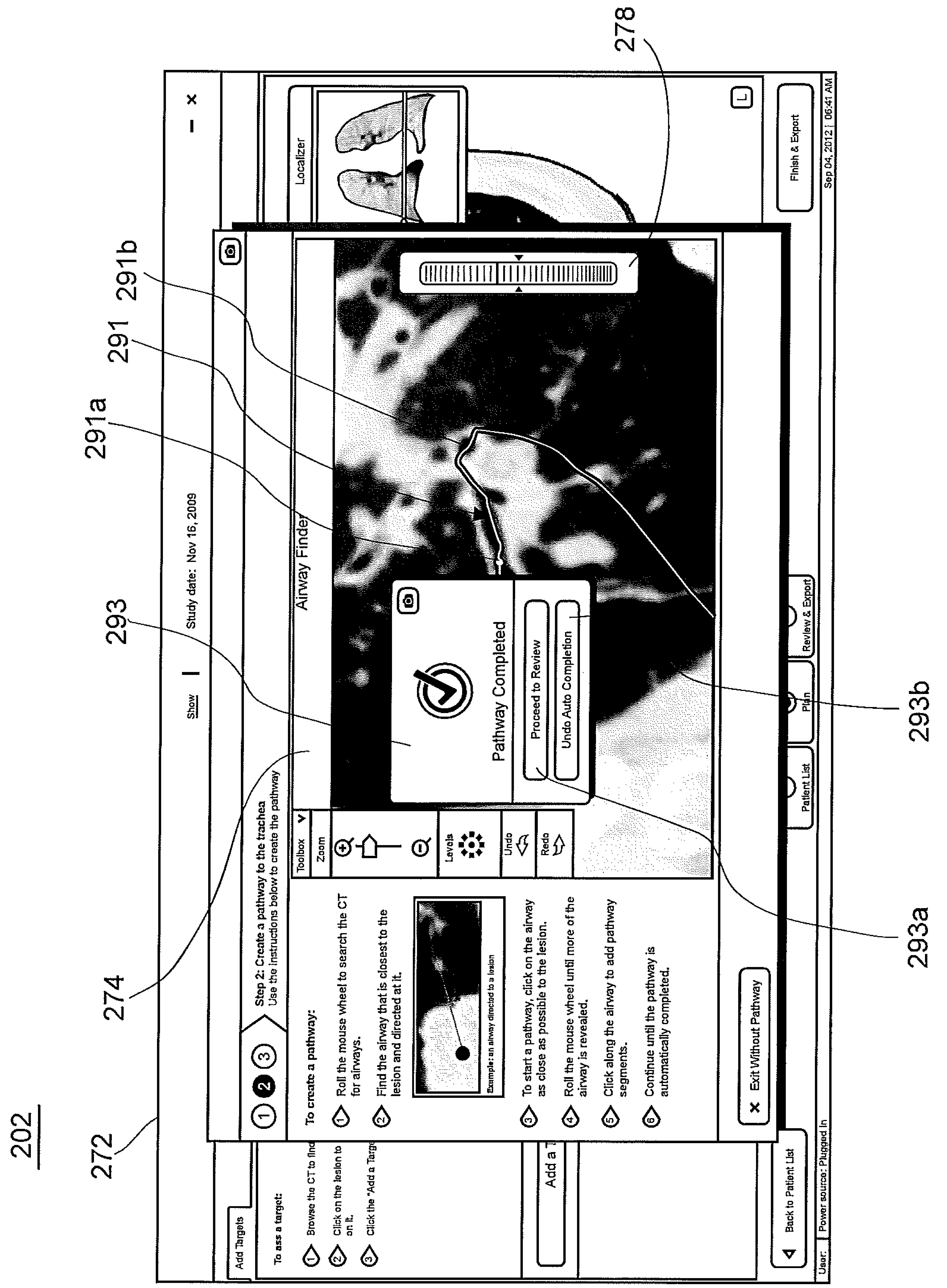

FIG. 11G

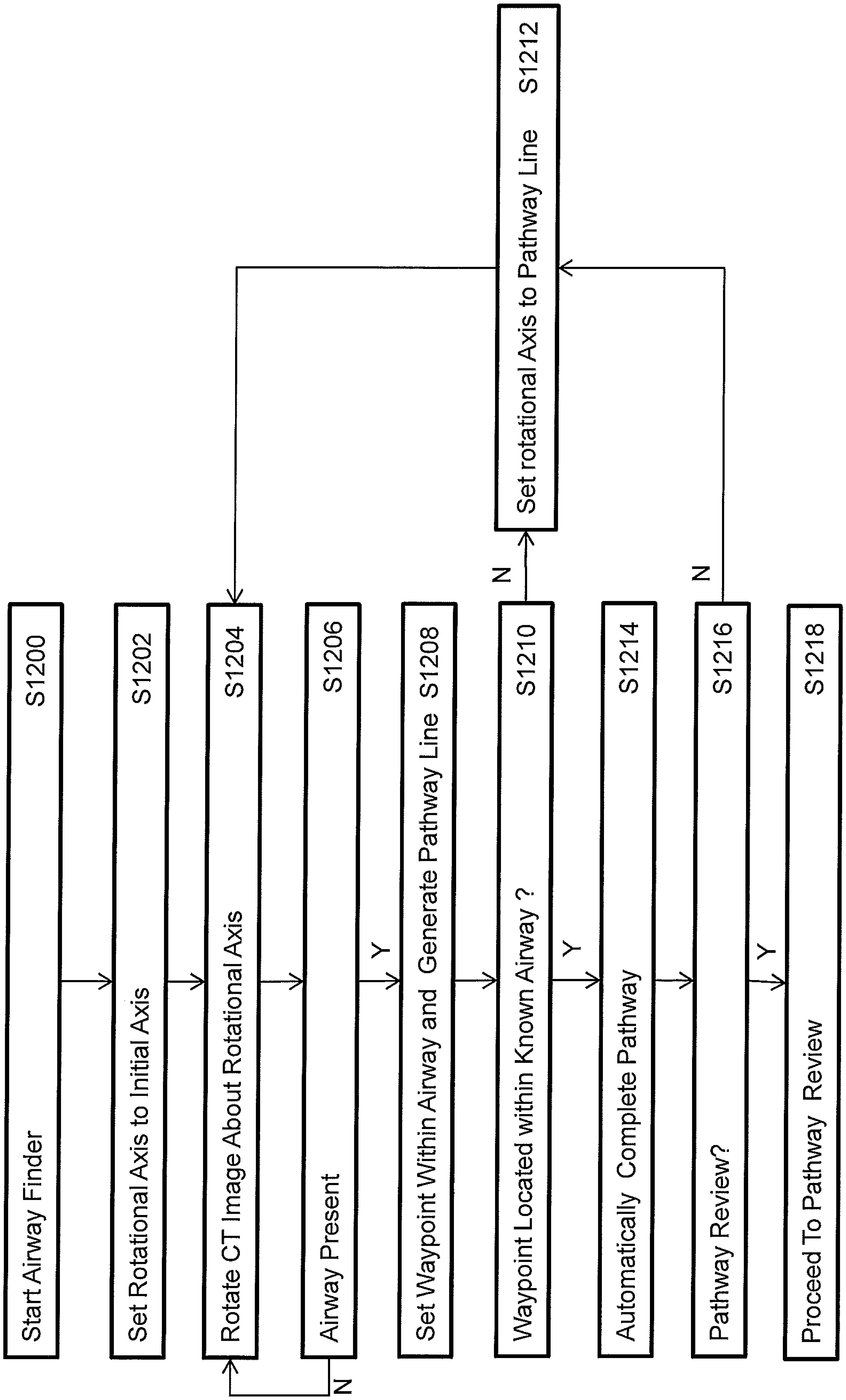
Start Airway Finder
S1200
Set Rotational Axis to Initial Axis
S1202
Rotate CT Image About Rotational Axis
S1204
Airway Present
S1206
N
Y
Set Waypoint Within Airway and Generate Pathway Line
S1208
Waypoint Located within Known Airway ?
S1210
N
Y
Set rotational Axis to Pathway Line
S1212
Automatically Complete Pathway
S1214
Pathway Review?
S1216
N
Y
Proceed To Pathway Review
S1218

FIG. 12

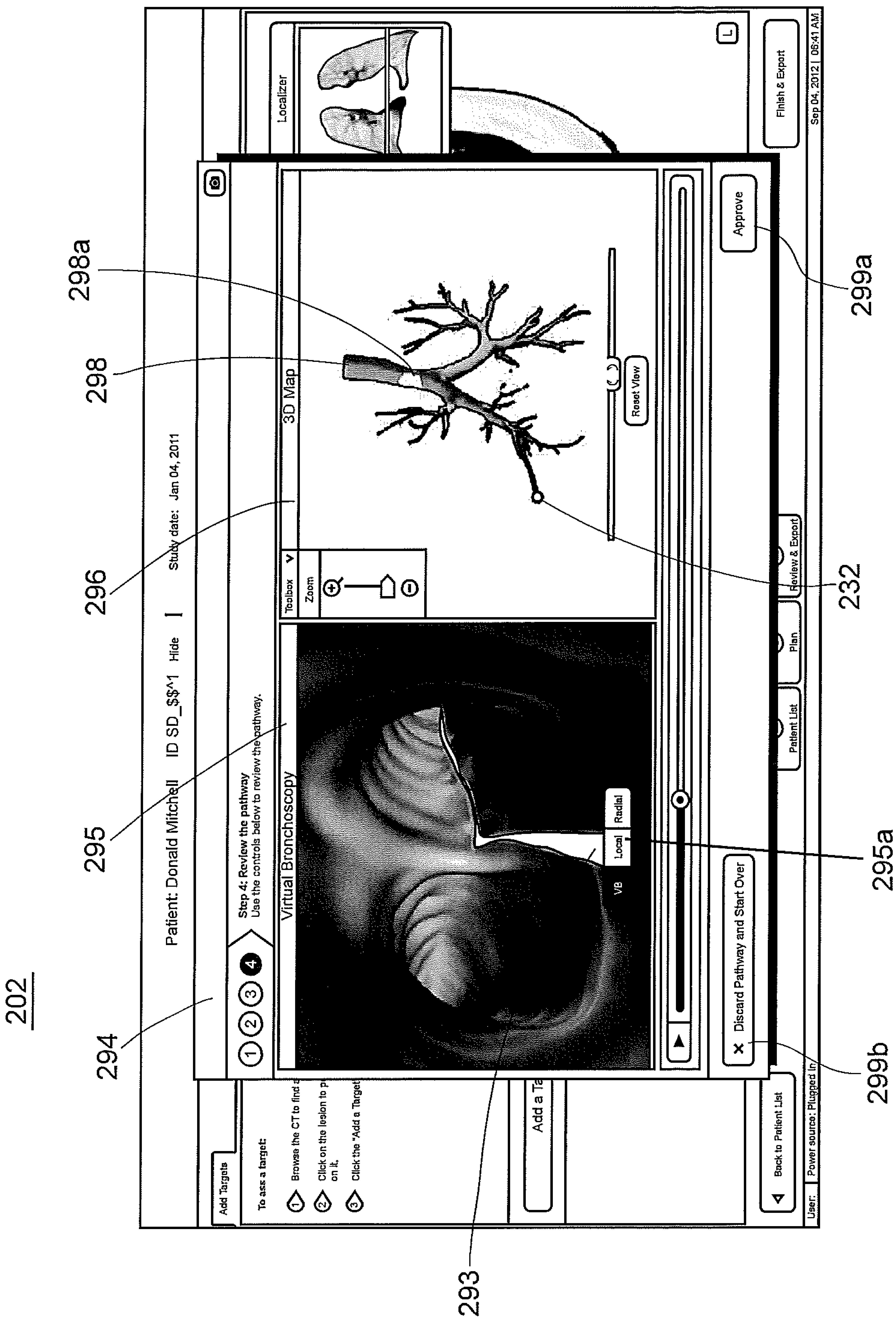
202
294
295
296
298
298a
299a
232
295a
299b
293
Patient: Donald Mitchell ID SD_$$^1 Hide Study date: Jan 04, 2011
Step 4: Review the pathway
Use the controls below to review the pathway.
Virtual Bronchoscopy
3D Map
Toolbox
Zoom
Reset View
Local
Radial
VB
Localizer
Approve
Discard Pathway and Start Over
Patient List
Plan
Review & Export
Finish & Export
Back to Patient List
Add Targets
To ass a target:
Sep 04, 2012 | 06:41 AM

FIG. 13

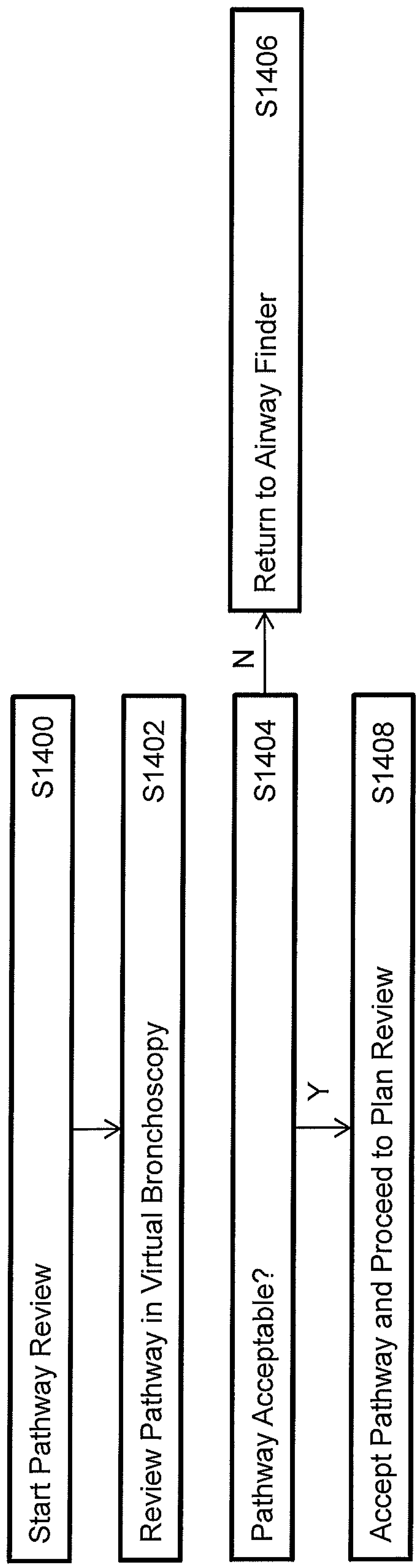
Start Pathway Review
S1400
Review Pathway in Virtual Bronchoscopy
S1402
Pathway Acceptable?
S1404
N
Y
Return to Airway Finder
S1406
Accept Pathway and Proceed to Plan Review
S1408

FIG. 14

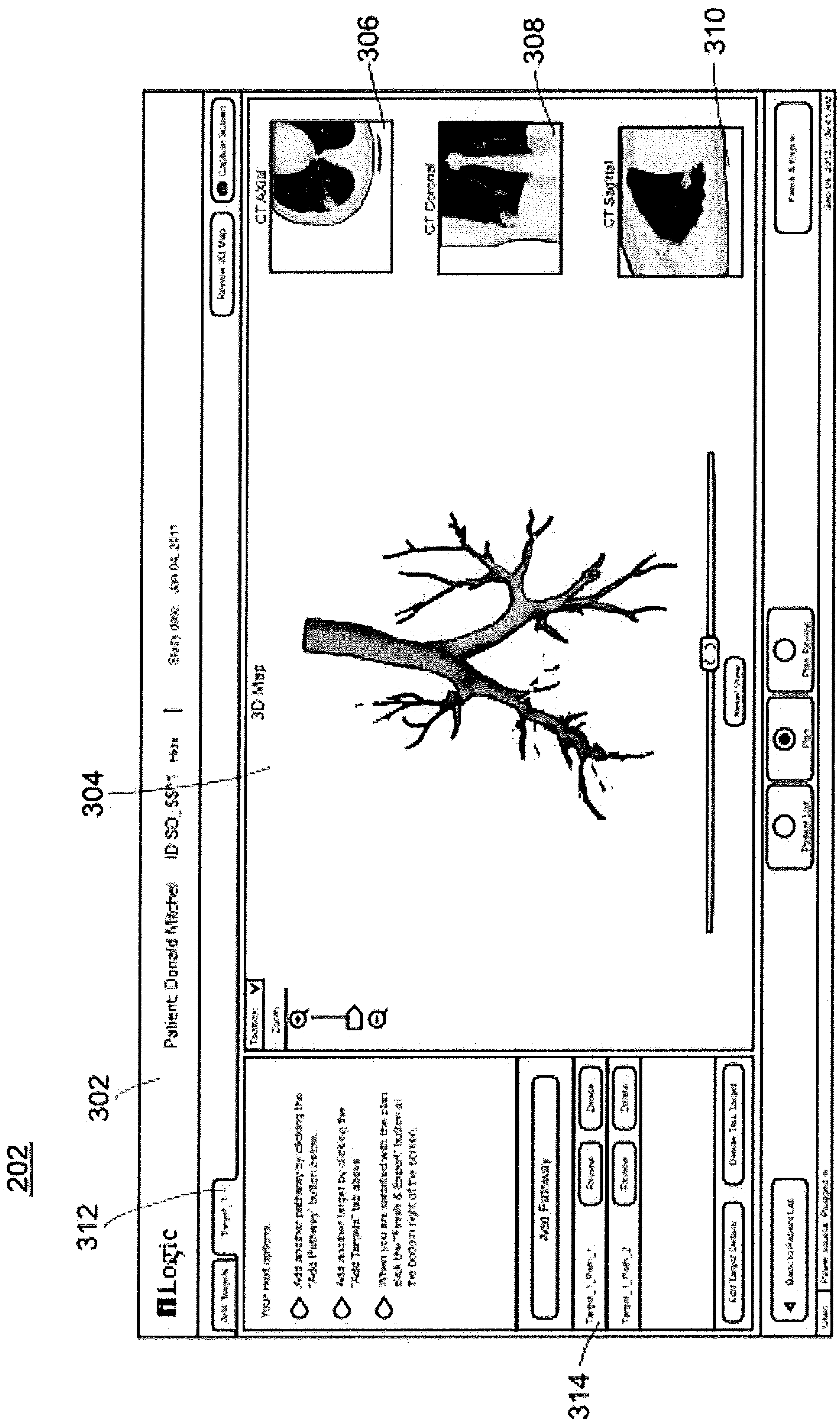
202
302
304
306
308
310
312
314
Patient: Donald Mitchell
3D Map
CT Axial
CT Coronal
CT Sagittal
Add Pathway

FIG. 15

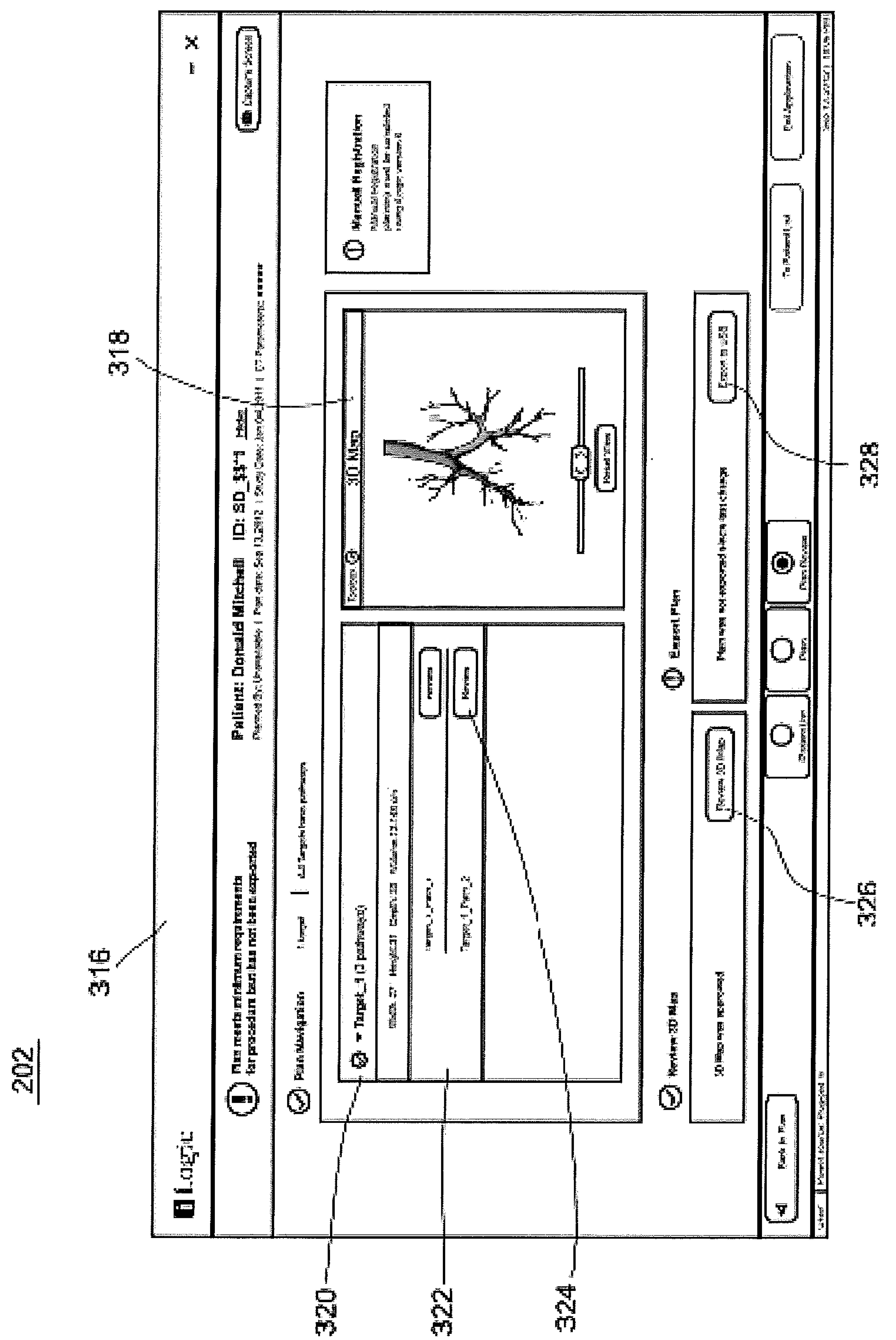

FIG. 16

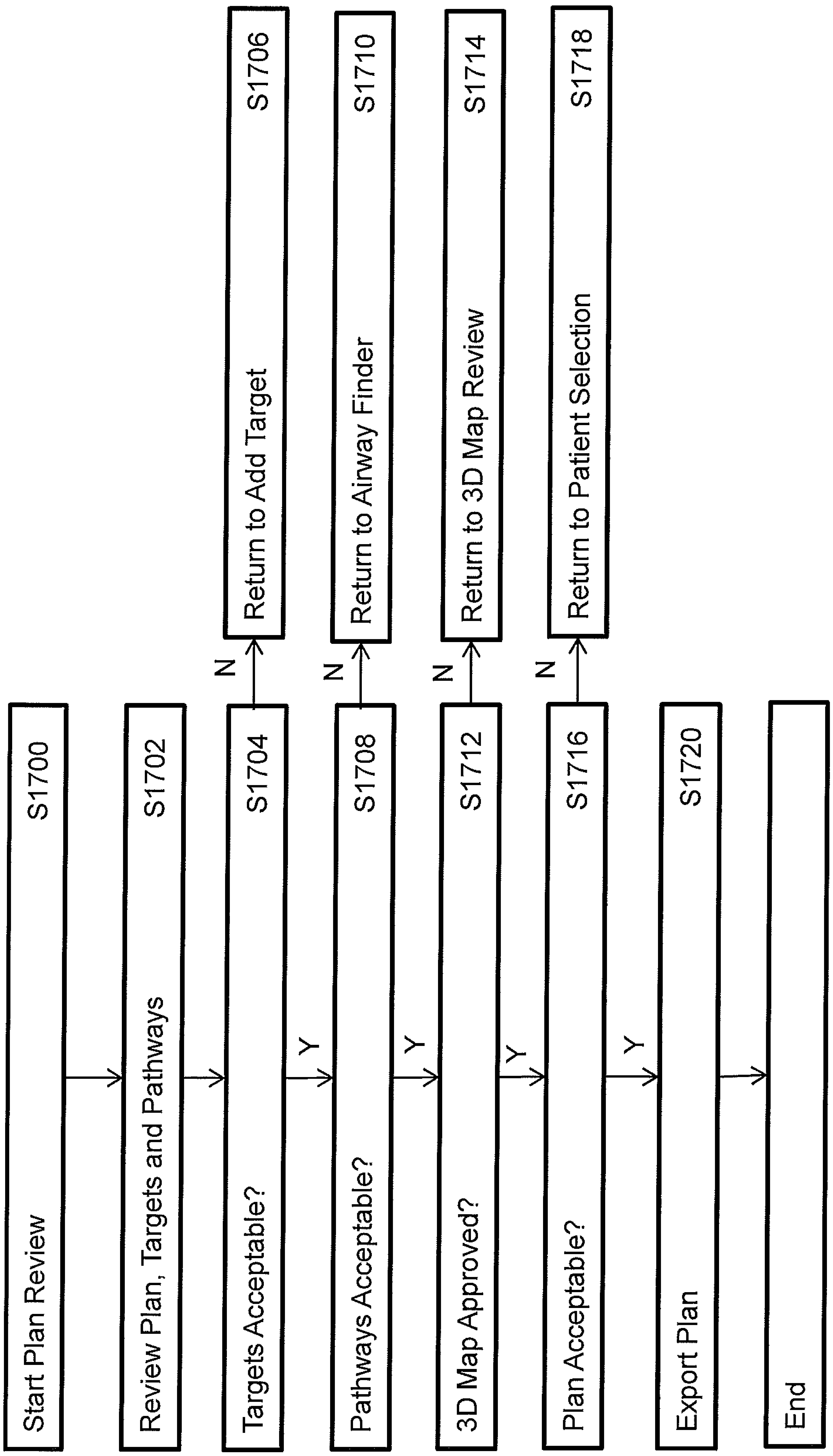
Start Plan Review
S1700
Review Plan, Targets and Pathways
S1702
Targets Acceptable?
S1704
N
Return to Add Target
S1706
Y
Pathways Acceptable?
S1708
N
Return to Airway Finder
S1710
Y
3D Map Approved?
S1712
N
Return to 3D Map Review
S1714
Y
Plan Acceptable?
S1716
N
Return to Patient Selection
S1718
Y
Export Plan
S1720
End

FIG. 17

PATHWAY PLANNING SYSTEM AND METHOD

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 13/839,224 filed on Mar. 15, 2013, the entire contents of which are incorporated by reference herein for all purposes.

BACKGROUND

Technical Field

The present disclosure relates to a system and method for planning a pathway through an anatomical luminal network of a patient.

Discussion of Related Art

During a surgical procedure clinicians often use CT images for determining a plan or pathway for navigating through the luminal network of a patient. It is often difficult, however, for the clinician to effectively plan a pathway based on CT images alone, especially in the smaller branches of the bronchial tree where CT images typically do not provide sufficient resolution for accurate navigation.

To assist a clinician in planning a pathway through a luminal network, automated pathway planning systems and methods have been implemented that automatically generate a pathway from a target designated on a CT image to the an entry point of a patient, e.g., a patient's mouth, nose, other natural entry points or an artificial entry point such, for example, as an incision. One example of an automated pathway planning system and method can be found in U.S. Pat. No. 8,218,846, the entirety of which is incorporated herein by reference.

When using a fully automated pathway planning system, however, the medical device may reach the end of the pathway in an orientation where the working end of the medical device is not oriented toward the target. In this example, a side of the medical device may be oriented towards the target instead of the working end and it may be difficult or impossible for the clinician to gain access to the target with the working end. In particular, when navigating through the small airways of the bronchial tree it may be difficult or even impossible to flex or turn the working end of the medical device towards a target when the target is located perpendicular to the path of travel of the medical device through the small airways.

SUMMARY

Systems and methods for planning a pathway through an anatomical luminal network of a patient are provided.

In an aspect of the present disclosure, a system for planning a pathway through an anatomical luminal network of a patient is disclosed including a computing device including at least one processor; a display device in communication with the computing device; a user interface configured for display on the display device and configured to guide a user through a pathway planning procedure. The user interface includes a patient selection window configured to receive a user input to select a patient having CT image data on which to perform pathway planning; a target selection window configured to receive a user input to select at least one target from the CT image data; and an airway finder window configured to generate at least one pathway from the at least one target to an entry point of the anatomical luminal network in response to a user input.

In an aspect of the present disclosure, the patient selection window is configured to import patients and CT image data from at least one memory device associated with the computing device.

In an aspect of the present disclosure, the at least one processor is configured to generate a three-dimensional CT volume from the CT image data selected by the user.

In an aspect of the present disclosure, the at least one processor is configured to generate a three-dimensional model of the patient's bronchial tree from the CT image data selected by the user for displaying on the display.

In an aspect of the present disclosure, the target selection window includes: a CT image window configured to display a slice of the CT image data; a localizer window configured to display an image of at least one lung, the localizer window including a localizer configured to identify a location of the displayed slice relative to the at least one lung; and a target selection element configured to select the target from a displayed slice of CT image data in response to a user input.

In an aspect of the present disclosure, the CT image window is configured to display at least one other slice of the CT image data in response to a user input and the localizer is configured to move relative to the image of the at least one lung to identify the location of the displayed at least one other slice relative to the at least one lung.

In an aspect of the present disclosure, the airway finder window is configured to display a CT image including the selected at least one target, the CT image rotatable about a pre-defined axis to assist the user in identifying an airway of the anatomical luminal network.

In an aspect of the present disclosure, the pre-defined axis is an axis defined from the target to a known airway of the anatomical luminal network.

In an aspect of the present disclosure, the pre-defined axis is an axis defined from the target to a portion of a trachea in the anatomical luminal network.

In an aspect of the present disclosure, the pre-defined axis is an axis defined by a pathway from the target to a waypoint.

In an aspect of the present disclosure, the pre-defined axis is an axis defined by a pathway from a first waypoint to a second waypoint.

In an aspect of the present disclosure, the airway finder window further includes a rotation interface configured to identify an amount of rotation of the CT image about the pre-defined axis relative to an initial rotational orientation of the CT image.

In an aspect of the present disclosure, a method for planning a pathway through an anatomical luminal network of a patient is disclosed including the steps of: importing CT image data of a patient selected by a user input; generating a three-dimensional CT volume from the CT image data; displaying a slice of the three-dimensional CT volume; receiving a user input identifying a target; defining an axis of rotation from the identified target to a known airway of the three-dimensional CT volume; rotating a slice of the three-dimensional CT volume about the axis of rotation; receiving an input from a user indicating a location for a new waypoint in an airway of the rotated slice; setting a first waypoint in the identified airway; and generating a first pathway from the target to the first waypoint.

In an aspect of the present disclosure, the method further includes the steps of:

determining if the first waypoint is located in a known airway of the three-dimensional CT volume; and automatically completing a pathway from the first waypoint to the entry point if the first waypoint is located in a known airway.

In an aspect of the present disclosure, the method further includes the steps of: defining the axis of rotation along the first pathway; rotating a slice of the three-dimensional CT volume about the axis of rotation; receiving an input from a user indicating a location for a new waypoint in an airway of the rotated slice; setting a second waypoint in the identified airway; and generating a second pathway from the first waypoint to the second waypoint.

In an aspect of the present disclosure, the method further includes the steps of: determining if the second waypoint is located in a known airway of the three-dimensional CT volume; and automatically completing a pathway from the second waypoint to the entry point if the second waypoint is located in a known airway.

In an aspect of the present disclosure, a non-transitory computer-readable storage medium encoded with a program is disclosed, that, when executed by a processor causes a user interface to perform the steps of: importing CT image data of a patient selected by a user input; generating a three-dimensional CT volume from the CT image data; displaying a slice of the three-dimensional CT volume; receiving a user input identifying a target; defining an axis of rotation from the identified target to a known airway of the three-dimensional CT volume; rotating a slice of the three-dimensional CT volume about the axis of rotation; receiving an input from a user indicating a location for a new waypoint in an airway of the rotated slice; setting a first waypoint in the identified airway; and generating a first pathway from the target to the first waypoint.

In an aspect of the present disclosure, the program further causes the user interface to perform the steps of: determining if the first waypoint is located in a known airway of the three-dimensional CT volume; and automatically completing a pathway from the first waypoint to the entry point if the first waypoint is located in a known airway.

In an aspect of the present disclosure, the program further causes the user interface to perform the steps of: defining the axis of rotation along the first pathway; rotating a slice of the three-dimensional CT volume about the axis of rotation; receiving an input from a user indicating a location for a new waypoint in an airway of the rotated slice; setting a second waypoint in the identified airway; and generating a second pathway from the first waypoint to the second waypoint.

In an aspect of the present disclosure, the program further causes the user interface to perform the steps of: determining if the second waypoint is located in a known airway of the three-dimensional CT volume; and automatically completing a pathway from the second waypoint to the entry point if the second waypoint is located in a known airway.

Any of the above aspects and embodiments of the present disclosure may be combined without departing from the scope of the present disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

Objects and features of the presently disclosed system and method will become apparent to those of ordinary skill in the art when descriptions of various embodiments thereof are read with reference to the accompanying drawings, of which:

FIG. **1** is a schematic diagram of a computing device for pathway planning in accordance with an embodiment of the present disclosure;

FIG. **2**A is a view of a CT scan image of a patient's lungs taken from the Axial direction in accordance with an embodiment of the present disclosure;

FIG. **2**B is perspective view a patient's body illustrating the Axial direction in accordance with an embodiment of the present disclosure;

FIG. **2**C is a view of a CT scan image of a patient's lungs taken from the Coronal direction in accordance with an embodiment of the present disclosure;

FIG. **2**D is perspective view of a patient's body illustrating the Coronal direction in accordance with an embodiment of the present disclosure;

FIG. **2**E is a view of a CT scan image of a patient's lungs taken from the Sagittal direction in accordance with an embodiment of the present disclosure;

FIG. **2**F is perspective view of a patient's body illustrating the Sagittal direction in accordance with an embodiment of the present disclosure;

FIG. **3** is a flow chart illustrating the four phases of pathway planning in accordance with an embodiment of the present disclosure;

FIG. **4** is an illustration of a user interface for the selection of patient data in accordance with an embodiment of the present disclosure;

FIG. **5** is a flow chart of a method of selecting patient data in accordance with an embodiment of the present disclosure;

FIG. **6** is an illustration of a user interface for adding a target to a pathway plan in accordance with an embodiment of the present disclosure;

FIG. **7** is a flow chart of a method of adding a target to a pathway plan in accordance with an embodiment of the present disclosure;

FIG. **8** is an illustration of a user interface for editing target details of an added target in accordance with an embodiment of the present disclosure;

FIG. **9** is an illustration of a user interface for reviewing a 3D map in accordance with an embodiment of the present disclosure;

FIG. **10** is a flow chart of a method of reviewing a 3D map in accordance with an embodiment of the present disclosure;

FIG. **11**A is an illustration of a user interface for finding a pathway from a target to an entry point of a patient;

FIG. **11**B is an illustration of the user interface of FIG. **11**A after a CT image of the user interface has been rotated about an initial axis;

FIG. **11**C is a perspective view of a 3D model of a patient's bronchial tree, illustrating an initial axis of rotation in accordance with an embodiment of the present disclosure;

FIG. **11**D is an illustration of the user interface of FIG. **11**B after a waypoint has been added and a pathway between the target and the waypoint has been created with the CT image rotated about the axis of the pathway;

FIG. **11**E is an illustration of the user interface of FIG. **11**D after a second waypoint has been added and a second pathway between the waypoint and the second waypoint has been created;

FIG. **11**F is an illustration of the user interface of FIG. **11**E after the CT image has been rotated about the axis of the second pathway to display a known airway;

FIG. **11**G is an illustration of the user interface of FIG. **11**F after a third waypoint has been added within the known airway and the pathway has been automatically completed;

FIG. **12** is a flow chart of a method of finding a known airway and creating a pathway in accordance with an embodiment of the present disclosure;

FIG. **13** is an illustration of a user interface for the reviewing a pathway accordance with an embodiment of the present disclosure;

FIG. **14** is a flow chart of a method of reviewing a pathway in accordance with an embodiment of the present disclosure;

FIG. **15** is an illustration of a user interface for the reviewing a target and pathway and for creating additional targets and pathways in accordance with an embodiment of the present disclosure;

FIG. **16** is an illustration of a user interface for the reviewing and exporting a pathway plan in accordance with an embodiment of the present disclosure; and

FIG. **17** is a flow chart of a method of reviewing and exporting targets, pathways, and pathway plans in accordance with an embodiment of the present disclosure.

DETAILED DESCRIPTION

Although the present disclosure will be described in terms of a specific embodiment, it will be readily apparent to those skilled in this art that various modifications, rearrangements and substitutions may be made without departing from the spirit of the present disclosure. The scope of the present disclosure is defined by the claims appended hereto.

Referring now to FIG. **1**, the present disclosure is generally directed to a pathway planning system **10** and method for planning a pathway through an anatomical luminal network of a patient for use during an operation. The pathway planning system **10** may include a computing device **100** such as, for example, a laptop, desktop, tablet, or other similar device, having a display **102**, memory **104**, one or more processors **106** and/or other components of the type typically found in a computing device. Display **102** may be touch sensitive and/or voice activated, enabling display **102** to serve as both an input and output device. Alternatively, a keyboard (not shown), mouse (not shown), or other data input devices may be employed.

Memory **104** includes any non-transitory, computer-readable storage media for storing data and/or software that is executable by processor **106** and which controls the operation of the computing device **100**. In an embodiment, the memory **104** may include one or more solid-state storage devices such as flash memory chips. In an alternative embodiment, the memory **104** may be mass storage connected to the processor **106** through a mass storage controller (not shown) and a communications bus (not shown). Although the description of computer-readable media contained herein refers to a solid-state storage, it should be appreciated by those skilled in the art that computer-readable storage media can be any available media that can be accessed by the processor **106**. That is, computer readable storage media includes non-transitory, volatile and non-volatile, removable and non-removable media implemented in any method or technology for storage of information such as computer-readable instructions, data structures, program modules or other data. For example, computer-readable storage media includes RAM, ROM, EPROM, EEPROM, flash memory or other solid state memory technology, CD-ROM, DVD, or other optical storage, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices, or any other medium which can be used to store the desired information and which can be accessed by the computing device **100**.

Computing device **100** may also include a network module **108** connected to a distributed network or the internet via a wired or wireless connection for the transmission and reception of data to and from other sources. For example, computing device **100** may receive computed tomographic (CT) images of a patient from a server, for example, a hospital server, internet server, or other similar servers, for use during pathway planning. Patient CT images may also be provided to computing device **100** via a removable memory **104**.

A pathway planning module **200** includes a software program stored in memory **104** and executed by processor **106** of the computing device **100**. As will be described in more detail below, pathway planning module **200** guides a clinician through a series of steps to develop a pathway plan for later use during a medical procedure. Pathway planning module **200** communicates with a user interface module **202** for displaying visual interactive features to a clinician on the display **102** and for receiving clinician input.

As used herein, the term "clinician" refers to any medical professional (i.e., doctor, surgeon, nurse, or the like) or other user of the pathway planning system **10** involved in planning, performing, monitoring and/or supervising a medical procedure involving the use of the embodiments described herein.

Referring temporarily to FIGS. **2**A-**2**F, as a practical matter the most effective method of identifying targets involves the use of a computed tomographic (CT) image. By way of introduction, the use of CT images as a diagnostic tool has become routine and CT results are frequently the primary source of information available to a clinician regarding the size and location of a lesion, tumor or other similar target of interest. This information is used by the clinician for planning an operative procedure such as a biopsy, but is only available as "offline" information which must typically be memorized to the best of the practitioner's ability prior to beginning a procedure. CT images are typically obtained by digitally imaging a patient in slices in each of the Axial, Coronal and Sagittal directions. For example, FIG. **2**A illustrates a slice of a CT image taken from the Axial direction, i.e., as though looking parallel to the spine of the patient as illustrated in FIG. **2**B. FIG. **2**C illustrates a slice of a CT image taken from the Coronal direction, i.e., from a birds eye view of the patient as illustrated in FIG. **2**D. FIG. **2**E illustrates a slice of a CT image taken from the Sagittal direction, i.e., from a side of the patient as illustrated in FIG. **2**F. A clinician may review the CT image data slice by slice from each direction when attempting to identify or locate a target.

Referring now to FIG. **3**, in an embodiment, pathway planning using the pathway planning module **200** may be performed in four separate phases. In a first phase S**1**, a clinician selects a patient for pathway planning. In a second phase S**2**, the clinician adds a target. In a third phase S**3**, the clinician creates the pathway to the target. Finally, in the fourth phase S**4**, the clinician reviews and accepts the plan and may export the plan for use in a medical procedure. The clinician may repeat either or both of the second and third phases S**2** and S**3** as needed to select additional targets and/or create additional pathways for a particular patient. For example, the clinician may select additional targets and may create a pathway to each target. The clinician may also or alternatively create multiple pathways the same target. With reference to FIGS. **4**-**16**, each of stages S**1**-S**4** will now be described in more detail below.

As used herein, the term "window" refers to any screen, image, overlay, user interface or combination thereof, projected or provided on the display **102** by user interface **202**.

Referring now to FIGS. **4** and **5**, in phase **51**, user interface **202** presents a clinician with a window **210** for selecting patient data **212** on which to perform pathway planning. FIG. **4** illustrates user interface **202** including window **210** while FIG. **5** illustrates a method of selecting patient data according to an embodiment of the present disclosure. User interface **202** initially starts the method of selecting patient data at step S**500** by opening window **210** for the clinician's review. Window **210** includes a selectable source location menu **214** that provides the clinician with the ability to select a source from which patient data **212** is received for use in pathway planning. In step S**510** the clinician selects from a number of storage or memory devices including, for example, cd, dvd, blue-ray, other insertable optical media, universal serial bus (USB) memory devices, external or internal hard drives, solid state storage devices, or any other type of memory or storage **104** connected to or in data communication with computing device **100**, as described above. The window **210** may also provide access to patient data **212** stored in a remote location such as, for example, a server on a network or the internet. Source location menu **214** may allow the clinician to select a single source of patient data or may allow the clinician to select multiple sources of patient data at the same time. Source location menu **214** may also include an option to list patients from all sources. In step S**504**, the clinician may search through the list of patients or may input a search term in a search box **216** to narrow down the list of patients to those meeting a selected criteria such as, for example, a patient's first or last name, ID number, date of birth or other similar criteria. Once the clinician has selected the desired patient, the clinician proceeds to step S**506**.

In step **506**, once a patient is selected by the clinician, a drop down menu **218** is displayed for the patient including a list of the patient's available CT images **220** and any pathway plans **222** for the selected patient that have been previously created for each CT image **220**. The clinician may choose to create a new plan based on the CT image **220** by selecting the create new plan option **224** and proceeding to step S**510** or may open a previously created plan by selecting an open plan option **226** and proceeding to step S**514**, if a previously created plan is present for the selected CT image **220**. When the create new plan option **224** is selected, the CT images **220** are imported, preferably in a DICOM format, into the pathway planning module **200**. The computing device **100** processes the CT images **220** and assembles them into a three-dimensional CT volume by arranging the CT images **220** in the order they were taken and spacing them apart according a distance between slices set on the CT scanning device when they were taken. Pathway planning module **200** may perform a data fill function to create a seamless three-dimensional (3D) model or CT volume of the patient's bronchial tree. The pathway planning module **200** uses the newly-constructed CT volume to generate a three-dimensional map of the airways in the bronchial tree. The three dimensional map can either be skeletonized, such that each airway is represented as a line, or it may include airways having dimensions representative of their respective diameters. Preferably, when the three dimensional map is being generated, the airways are marked with an airflow direction (inhalation, exhalation, or separate arrows for each) for later use. Technologies for generating three-dimensional CT volumes and models are described in commonly assigned U.S. Pat. Nos. 6,246,784 and 6,345,112 both to Summers et al., as well as the references cited therein, all of which are hereby incorporated herein by reference.

Window **210** also includes a capture screen option **228** that allows the clinician to capture an image of the current screen shown on the display **102**, for example, window **210**, and save the captured image to memory. The capture screen option **228** may also be configured to remove patient specific data from the captured image to protect patient privacy. The removal of patient specific data may be an option selectable by the clinician and may be set to "on" by default.

Referring now to FIGS. **6-8**, if the clinician has selected the create new plan option **224** from window **210**, the method proceeds to step S**512** and phase S2, adding a target. FIGS. **6** and **8** illustrate user interface **202** including windows **230** and **244** while FIG. **7** illustrates a method of adding a target according to an embodiment of the present disclosure. When phase S2 is initiated the method proceeds to step S**700** and user interface **202** opens a window **230** for identification and selection of a target **232** on which to perform pathway planning. In window **230**, the clinician is provided with a slice **234** of the CT image data in a main window **236**. The slice **234** may be taken from the CT image data in any one of the Axial, Coronal and Sagittal directions. The clinician may freely switch the slice **234** shown in the main window **236** between slices **234** from the Axial, Coronal and Sagittal directions at any time. In the illustrated example, a slice **234** from the Axial CT image data is provided. It is important to note that by only showing a single slice and direction at a time, for example, only a slice **234** from the Axial CT image data, the clinician is provided with a simple and clean interface from which to select a target. The clinician may manipulate and relocate the image of the selected slice **234** in the main window **236** and may zoom in or out on the selected slice **234** to obtain an enlarged or reduced view of a particular portion of the selected slice **234**.

Window **230** also includes a localizer **238** which provides a general overview of the patient's CT image data for use by the clinician. In the illustrated example, localizer **238** provides a localizer window **240** including generic view of a patient's lungs from the Coronal direction. The localizer window **240** may, for example, display a CT image from the Coronal direction, a fluoroscopy-like image, or other similar images that provide a clinician with a view of the patient's lungs. Localizer **238** includes a location element **242**, for example, a line or bar, extending across localizer window **240** which provides a clinician with a location of the selected slice **234** displayed in main window **236** relative to the patient's lungs as displayed by the localizer **238**. Location element **242** is selectable by the clinician and moveable or slidable relative to the localizer window **240** to allow the clinician to scroll through the CT image slices of the patient's lungs displayed on the main window **236**. For example, the CT image slices may be scrolled through or displayed in a sequential order defined by the CT image data. The clinician may also or alternatively click on or select a portion of the localizer window **240** to move localizer **238** to the selected location in the patient's lungs. The clinician may also or alternatively scroll through the CT image slices of the patient's lungs displayed in the main window **236** via an input device such as, for example, a mouse wheel or other device without interacting directly with user interface **202**. When another direction is selected for display on main window **236**, for example, the Coronal direction, localizer **238** may display a generic view of one of the other directions, for example, the Axial or Sagittal direction. Localizer **238** provides the clinician with a general reference for where a particular lesion or other target **232** is located in the patient's lungs. Localizer **238** may also display one or more previously selected targets for the clinician's reference.

In step S702, the clinician scrolls through the CT image slices **234** to identify a target **232** on the CT image. In step S704, once a target **232** has been identified in the current CT slice **234**, the clinician may click on or otherwise select the target **232** from the main window **236** using a target selection element **243**, for example, a crosshair, mouse pointer, hand, or other similar selection element. The clinician may, for example, drag the CT image displayed on the main window **236** so that the target selection element **243** is positioned over the target **232**, or alternatively, may directly select target **232** by clicking on the target **232** using a mouse (not shown) or other input device. If display **102** is touch-sensitive, the clinician may touch the target **232** on display **102** to select the target **232**. The target **232** may then be added to the plan in step S706 by selecting the add a target option **245**.

Referring now to FIG. **8**, once a target **232** has been added, a target details window **244** is displayed by user interface **202**. Target details window **244** may overlay window **230** or may replace window **230**. Target details window **244** provides the clinician with the selected target **232** as shown in enlarged or zoomed versions of the Axial view **246**, Coronal view **248** and Sagittal view **250**. In step S708, the clinician may input width, height, and depth dimensions for the target **232**, name the target **232**, and add additional comments relating to the target **232**. In addition, a target sizing element **252**, e.g., a crosshair or other similar element, is positioned over the target **232** in each of views **246**, **248**, **250** and is manipulatable or movable by the clinician to center the target **232** in the target sizing element **252** in each view **246**, **248**, **250**. Target sizing element **252** also includes an adjustable boundary ring **254** that is manipulatable by the clinician to resize the dimensions of the target **232**. For example, the clinician may resize the boundary ring **254** on each of the Axial view **246**, Coronal view **248** and Sagittal view **250** to accurately define the dimensions of the target **232**. Boundary ring **254** may be circular, oval or other similar geometric shapes and the shape of the boundary ring **254** may be adjusted to substantially match the general dimensions of the target **232**. In an embodiment, boundary ring **254** may be adjusted in a non-geometric manner by the clinician, for example, a free-form manipulation of boundary ring **254**, to conform to non-geometric dimensions of the target **232**. It is important to note that because the target **232** is a three dimensional object such as, for example, a lesion, tumor, or the like, and each view **246**, **248**, **250** is taken from a different direction, manipulation and adjustment of the boundary ring **254** on one of the views **246**, **248**, **250** by the clinician may result in a change or adjustment of the boundary ring **254** in one or both of the remaining views **246**, **248**, **250**. In this manner the clinician may accurately select the target dimensions and the location of the target **232** in all three views, effectively mapping the target to specific coordinates and dimensions in a 3-D coordinate space. In step S710, once the dimensions and location of target **232** have been selected by the clinician the clinician selects the save target option **256** and proceeds to a review of the generated three dimensional map of the patient's bronchial tree in step S712.

Referring now to FIGS. **9** and **10**, after the clinician has selected the save target option **256** of window **230**, the method proceeds to step S**1000**, reviewing the 3D map of the bronchial tree. In step S**1000**, user interface **202** opens a window **260** for review of the three dimensional map generated by the pathway planning module **200**. Window **260** includes a three dimensional map window **262** displaying a three dimensional model **264** of the patient's bronchial tree and a scan window **266** displaying a CT image from one of the Axial, Coronal and Sagittal directions for the clinician's reference. In the illustrated embodiment, the CT image from the Coronal direction is displayed. The CT image from the Coronal direction is displayed because the Coronal direction provides images of the patient's bronchial tree from the bird's eye or frontal view and is more likely to display to the clinician major recognizable features of the bronchial tree, for example, trunks and branches of the major airways. By comparing the CT image to the three dimensional model **264**, the clinician is able to determine or verify that the three dimensional model **264** includes the major recognizable features of the patient's bronchial tree and also that there are no gross abnormalities in the three dimensional model **264** when compared to the CT image. In step S**1002**, the clinician rotates the three dimensional model as needed by manipulating a rotation slider **268** of three dimensional map window **262** to determine if the 3D map is acceptable. In step S**1004**, if the clinician is satisfied that the three dimensional model **264** is substantially accurate, for example, the major or central airways are sufficiently illustrated, the clinician selects the approve map option **270** and proceeds to the phase S3 and the airway finder. If the 3D map is not acceptable, the clinician proceeds to step S**1006** and returns to step S**500** to select new patient data, for example, a new patient or a new CT scan for the same patient.

Referring now to FIGS. **11**A-**11**G and **12**, after the clinician has selected the approve map option **270** of window **260**, the method proceeds to phase S3 and step S**1200** to start the airway finder. FIGS. **11**A-**11**B and **11**D-**11**G illustrate user interface **202** including window **272**, FIG. **11**C illustrates an initial axis "A" for use by the airway finder, and FIG. **12** illustrates a method of finding an airway and completing a pathway according to an embodiment of the present disclosure. In step S**1200**, referring initially to FIGS. **11**A-**11**C, user interface **202** opens a window **272** for creating a pathway from the target **232** to the an entry point of the patient, for example, a natural orifice such as the mouth or nose, or an artificial entry point such as an incision. Window **272** includes an airway finder **274** displaying a CT image **276** including the target **232** and a rotation interface **278** describing the rotation of the CT image **276** about a specified axis. In an embodiment, upon initial opening of window **272**, only the target **232** is shown on the CT image **276** of the airway finder window **274** and rotation indicators **280**, e.g., arrows **280***a* and rotation bar **280***b*, on a rotation interface **278** are aligned. Rotation interface **278** provides rotational information regarding a relative rotation of CT image **276** about the specified axis. Referring now to FIG. **11**B, a target marker **232**A is displayed on the CT image **276** and is positioned over the target **232** to illustrate the location of target **232** to the clinician. A lead line **232**B extends from a center of target marker **232**A and is moveable by the clinician through movement of a pointer, mouse or other input devices. For example, the movement of an input device by the clinician moves an end **232**C of lead line **232**B that extends away from the target **232**. The clinician uses lead line **232**B to select an appropriate airway as will be described in more detail below with respect to step S**1208**.

In an embodiment, referring briefly to FIG. **11**C, an initial axis "A" is set in step S**1202** upon the initial opening of window **272** and is defined along an axis taken from the target **232** to a central portion of the tracheal lumen of the patient. By defining the initial axis "A" along axis from the target **232** to the trachea, the likelihood that a clinician can find an airway near the target **232** that will connect the target

232 to the entry point is increased. This is due to the tree like or branching nature of the bronchial tree. In other embodiments, the initial axis "A" may be defined along an axis taken from the target **232** to any other portion of the patient's bronchial tree, for example, to a central portion of the closest main branch of bronchial tree or to the closest known airway of the 3D map of the patient's bronchial tree.

In step S**1204**, the clinician rotates the CT image **276** about the initial axis by, for example, rolling a mouse wheel, manipulating another input device, and/or by manipulating a portion of user interface **202**, for example, rotation interface **278**. As the clinician rotates the CT image **276** about the initial axis, indicators **280** on the rotation interface **278** move relative to one another, for example, the rotation bar **280***b* moves relative to the arrows **280***a*, in a corresponding direction along rotation interface **278** to indicate the amount of rotation relative to the initial view. When the rotation bar **280***b* reaches the end of rotation interface **278** after continued rotation in the same direction by the clinician, rotation bar **280***b* will disappear from the end of the rotation interface **278**, reappear on an opposite end of rotation interface **278**, and continue to slide along rotation interface **278** in the same direction. When the clinician has rotated the CT image **276** a full rotation about the initial axis, indicators **280**, e.g., arrows **280***a* and rotation bar **280***b*, will once again be aligned at the center of rotation interface **278**.

Referring now to FIGS. **11**B and **11**D, when rotating the CT image **276** about the initial axis, the clinician assesses the CT image **276** in step S**1206** to determine whether an airway **282** near the target **232** is present. For example, an area of darkness in the CT image **276** that extends away from the target **232** or extends near the target **232** may be an indication that an airway **282** is present. If the clinician determines that an airway **282** is present, the method proceeds to step S**1208** and the clinician positions end **232**C of lead line **232**B at the determined location within the airway **282** on the CT image **276** to create a pathway waypoint **282***a* on the CT image **276**. The pathway planning module **200** draws a pathway line **284** between the target **232** and the pathway waypoint **282***a* on the CT image **276** and proceeds to step S**1210**. In this way, the clinician defines the portion of the airway **282** closest to the target **232**. If no airway **282** is present, the clinician returns to step S**1204** and continues to rotate the CT image about the specified axis. If the pathway waypoint **282***a* is not positioned correctly or the clinician desires to look for another airway, the clinician may remove the pathway waypoint **282***a* and return to either of steps S**1204** or S**1208**.

In step S**1210**, pathway planning module **200** determines whether the pathway waypoint **282***a* selected by the clinician is located within a known airway of the three dimensional map generated by the pathway planning module **200**. If the pathway waypoint **282***a* is located within a known airway of the three dimensional map, the method proceeds to step S**1214** and the pathway is automatically completed by the pathway planning module **200** from the pathway waypoint **282***a* through the known airways of the three dimensional map to the trachea and the entry point of the patient, as further illustrated below for waypoint **282***a* in FIG. **11**G.

If the pathway waypoint **282** is not located within a known airway of the three dimensional map, the method proceeds to step S**1212**. Referring now to FIGS. **11**D and **11**E, airway finder **274** displays a CT image **286** including the target **232**, target marker **232***a*, pathway waypoint **282***a*, pathway line **284**, and rotation interface **278**, as described above. As illustrated in FIG. **11**D, a lead line **282***b* having an end **282***c* now extends from pathway waypoint **282***a.*

In step S**1212**, the specified axis is set to an axis defined by pathway line **284**. CT image **286** is rotatable about pathway line **284** instead of the initial axis "A" and rotation interface **278** displays the relative rotation of the CT image **286** about the axis defined by pathway line **284**. By defining the axis of rotation about pathway line **284**, the likelihood of the clinician finding airways on CT image **286** that connect to the airway **282** including the pathway waypoint **282***a* is increased. After the specified axis has been set to the axis of pathway line **284**, the method returns to step S**1204**. When rotating the CT image **286** about the axis defined by pathway line **284**, the clinician assesses the CT image **286** to determine whether an airway **288** connected to the pathway including pathway waypoint **282***a* is present as described above. If the clinician determines that an airway **288** is present in step S**1206**, the method proceeds to step S**1208** and the clinician positions end **282**C of lead line **282**B at the determined location within the airway **288** on the CT image **286** to create a pathway waypoint **288***a* on the CT image **286**. The pathway planning module **200** draws a pathway line **290** from pathway waypoint **282***a* to pathway waypoint **288***a* on the CT image **286**, as illustrated in FIG. **11**E. If the pathway waypoint **288***a* is not positioned correctly or the clinician desires to look for another airway, the clinician may remove the pathway waypoint **288***a* and return to either of steps S**1204** or S**1208**.

In step S**1210**, referring now to FIG. **11**F, the pathway planning module **200** determines whether the pathway waypoint **288***a* selected by the clinician is located within a known airway, e.g., airway **291**, of the three dimensional map generated by the pathway planning module **200**. If the pathway waypoint **288***a* is not located within a known airway of the three dimensional map, the method proceeds to step S**1212** and the clinician continues to set additional pathway waypoints as described above until a pathway waypoint is located within a known airway of the three dimensional map.

Referring now to FIG. **11**G, a pathway waypoint **291***a* has been added in the manner described above in airway **291**. In this illustration, airway **291** is a known airway of the three dimensional map. The method proceeds to step S**1214** and the pathway **291***b* is automatically completed by the pathway planning module **200** from the pathway waypoint **291***a* through the airway **291** and the known branches of the three dimensional map of the bronchial tree to the entry point of the patient. Once a pathway is automatically completed, the method proceeds to step S**1216** and a pathway completed window **292** is displayed by the user interface **202** providing the clinician with a proceed to pathway review option **293***a* and an undo automatic completion option **293***a*. The clinician may select the proceed to pathway review option **293***a* to proceed to step S**1218** and start review of the pathway. Alternatively, if the clinician would like to continue mapping waypoints using airway finder **274**, the clinician may select the undo automatic completion option **293***b* and return to step S**1212** for the creation of further pathway waypoints as described above.

In this manner a pathway plan is created for later use by a clinician during a procedure or operation. Because the clinician can manually select and create the pathway and pathway waypoints that are closest to the target **232** prior to automatic completion, the clinician is able create a pathway plan that directly controls the final orientation of a medical device at the end of the pathway plan relative to the target **232**. This allows the clinician to create a pathway plan for the medical device that will allow the medical device to travel along the small airways of the patient in a direction that will allow the working end of the medical device to be oriented generally toward the target **232**, where generally toward the target **232** includes any orientation from which the clinician may effectively gain access to the target **232** within the limits of the medical device used.

Referring now to FIGS. **13** and **14**, after the clinician has completed a pathway, the method proceeds step S**1400** and user interface **202** opens a window **294** for reviewing the pathway from the target **232** to the entry point of the patient. FIG. **13** illustrates user interface **202** including window **294** while FIG. **14** illustrates a method of reviewing a pathway according to an embodiment of the present disclosure. Window **294** includes a virtual window **295** and a three dimensional map window **296**. Three dimensional map window **296** displays a three dimensional model **298** of the patient's bronchial tree similar to three dimensional map window **262**. Virtual window **295** displays a CT-based "virtual bronchoscopy" which depicts simulated views similar to those of actual bronchoscope views and includes a view selection tab **295***a* for selecting between a virtual bronchoscopy view, a local view, and radial view. During the virtual bronchoscopy, the clinician may switch between the virtual, local and radial views as needed to review the pathway. The virtual bronchoscopy view displays a virtual visualization of the airways, derived from the CT data, that is an approximation of the video image from a bronchoscope, the local view displays an elevated perspective view of a cross-section of the CT volume through the current navigation location, and the radial view displays a cross-section of the CT volume that is perpendicular to the navigation location and local pathway segment. The technology of virtual bronchoscopy is described in commonly assigned U.S. Pat. Nos. 6,246,784 and 6,345,112 both to Summers et al., as well as the references cited therein, all of which are hereby incorporated herein by reference.

In step S1402, once the pathway has been created by the clinician, the user reviews the plan, targets and pathways by following a fly-through virtual bronchoscopy on virtual window **295**. The user interface **202** generates a line **300** in virtual window **295** which represents the created pathway. The clinician follows the line **300** from the entry point through the trachea and through the airways of the patient's bronchial tree until the line **300** reaches the target **232**. As can be appreciated, as the clinician follows the line **300** through the increasingly smaller airways of the patient's bronchial tree, the ability of the pathway planning module **200** to resolve the smaller airways is increasingly difficult due to a lack of resolution in the imported CT images. Because of this lack of resolution, the simulated views of the virtual bronchoscopy displayed in virtual window **295** may eventually fail to depict a clear airway lumen. Regardless, the target **232** and line **300** will be displayed in the virtual window **295** to allow the clinician to utilize the system for pathway planning purposes.

As the clinician follows the line **300** through the patient's bronchial tree to the target **232**, a corresponding marker **298***a* travels along the three dimensional model **298** to the target **232** indicating a location of the simulated view of the virtual window **295** relative to the three dimensional model **298**. In step S**1404**, after reviewing the virtual bronchoscopy the clinician determines whether the pathway is acceptable. If the pathway is acceptable the clinician may select the approve option **299***a* and the method proceeds to steps S**1408**. If the pathway is not acceptable, the method proceeds to steps S**1406** and the clinician may select the discard pathway and start over option **299***b* to return to the airway finder window **272** to edit the pathway or create a new pathway.

Referring now to FIGS. **15-17**, once the clinician has reviewed and accepted the pathway, the method proceeds to phase S**4** and step S**1700**. FIGS. **15** and **16** illustrate user interface **202** including windows **302** and **316**, respectively, while FIG. **17** illustrates a method of reviewing a plan according to an embodiment of the present disclosure. In step S**1700**, user interface **202** opens a window **302** including a three dimensional map window **304** and views of each of the Axial **306**, Coronal **308** and Sagittal **310** directions displaying the selected pathway. Window **302** includes target tabs **312** and a pathway list **314**. Target tabs **312** allow the clinician to add additional targets and select already identified targets for further review. Pathway list **312** allows the clinician to review the pathways associated with a selected target tab **312** and to add a pathway for the selected target tab **312**. In step S**1704**, the clinician determines if the targets are acceptable. If the targets are not acceptable, the method proceeds to step S**1706** and the pathway planning module **200** returns the clinician to the add a target window **230** to add a new target, as described above. If the targets are acceptable, the method proceeds to step S**1708** and the clinician determines if the pathways are acceptable. If the pathways are not acceptable the method proceeds to step S**1710** and the pathway planning module **200** returns the clinician to the airway finder window **272** for creation of additional pathways, as described above. If both the targets and the pathways are acceptable, the clinician selects the finish and export option **315** and proceeds to plan review in step S**1716**.

Referring now to FIG. **16**, in step S**1716** user interface **202** opens a window **316** including a three dimensional map window **318** and a list of the targets **320** identified for the selected plan. Each target **320** is selectable by the clinician to display the associated pathways **322** and each pathway **322** is reviewable by the clinician through the selection of a review option **324**. Window **316** also provides an indication of whether the three dimensional map has been reviewed and approved and whether the current plan has been exported. In step S**1712**, if the 3D map has not been approved, the clinician may re-review the three dimensional map by selecting the review 3D map option **326**. If the review 3D map option **326** has been selected, the method proceeds to step S**1714** and the pathway planning module **200** returns the clinician to the review 3D map window **260** described above. If the 3D map has been approved, the method proceeds to step S**1716** and the clinician determines whether the overall plan is acceptable. If the plan is not acceptable, the method proceeds to step S**1718** and the pathway planning module **200** returns the clinician to the patient selection window **210** described above. If the clinician is satisfied with the plan, the method proceeds to step S**1720** and the clinician may export the plan for use during a surgical procedure by selecting the export option **328**. The plan may be exported to any form of non-transitory computer readable medium, memory or storage device as described above for memory **104** including, for example, a memory or storage on the device **100**, a removable storage device, exported by transmission across a wired or wireless connection to a remote or server memory, etc.

With reference to FIGS. **4**, **6**, **15** and **16** the user interface **202** may include one or more navigation bars that are manipulatable by the clinician to return to or repeat any of the above phases and/or steps. For example, as illustrated in FIG. **4**, the clinician may manipulate a navigation bar **330** to switch between the phases. The clinician may also be provided with the option to return to a previous step or window in any of the user interface **202** windows.

As noted above, the present disclosure employs CT images for the pathway planning. CT images are also typically used by the clinician during a medical procedure for the navigational purposes. The CT images are preferable to other imaging modalities because they have their own system of coordinates. Matching two systems of coordinates, e.g., that of the CT images and that of the patient, is commonly known as registration. Registration is generally performed by identifying locations in both the CT images and on or inside the body, and measuring their coordinates in both systems.

Methods of manual and semi-automated registration of CT data and patient data are described in detail in for example U.S. Pat. No. 7,233,820 assigned to Covidien LP and incorporated herein by reference. Because manual registration is somewhat time consuming and requires multiple steps, many practitioners rely on the automatic registration techniques described below. However, in some instances, particularly if the CT image data is not of sufficient quality it may still be necessary or desirable to conduct manual registration.

Automatic registration has become the norm for most procedures because while the manual fiducial point designation of the above referenced registration techniques is highly effective, the choice of number of points sampled necessarily represents a tradeoff between accuracy and efficiency. Similarly, while the semi-automated technique is a viable option it requires an image sensor at the distal end of the catheter assembly which adds increased complexity to the system.

Automatic registration techniques are described in detail in commonly assigned U.S. patent application Ser. No. 12/780,678, which is incorporated herein by reference in its entirety. Automatic registration between a digital image of a branched structure and a real-time indicator representing a location of a sensor inside the branched structure is achieved by using a sensor to "paint" a digital picture of the inside of the structure. Once enough location data has been collected, registration is achieved. The registration is "automatic" in the sense that navigation through the branched structure necessarily results in the collection of additional location data and, as a result, registration is continually refined.

Although embodiments have been described in detail with reference to the accompanying drawings for the purpose of illustration and description, it is to be understood that the inventive processes and apparatus are not to be construed as limited thereby. It will be apparent to those of ordinary skill in the art that various modifications to the foregoing embodiments may be made without departing from the scope of the disclosure.

What is claimed is:

1. A system for planning a pathway through an anatomical luminal network of a patient, the system comprising:

a computing device including at least one processor;

a display device in communication with the computing device; and

a user interface configured for display on the display device and configured to guide a user through a pathway planning procedure, the user interface comprising:

an airway finder window configured to:

generate at least one pathway from a target to an entry point of the anatomical luminal network in response to a user input;

display a CT image, the displayed CT image being rotatable about an initial axis of rotation extending between the target and a trachea of the luminal network, wherein the airway finder window includes a rotation interface configured to display an amount of rotation of the CT image;

determine whether a waypoint is inside or outside an airway;

in response to determining that the waypoint is outside an airway, redefine, by the at least one processor, the initial axis of rotation as a redefined axis of rotation extending between the target and the waypoint such that the displayed CT image is rotatable about the redefined axis of rotation; and

in response to determining that the waypoint is inside an airway, generate a pathway from the waypoint to a trachea and display the displayed CT image as rotatable about the initial axis of rotation.

2. The system according to claim **1**, wherein the user interface further comprises:

a patient selection window configured to:

receive a user input to select a patient having computed tomographic (CT) image data on which to perform pathway planning; and

import patient data and CT image data from at least one memory device associated with the computing device, and

a target selection window configured to receive a user input to select at least one target from the CT image data, wherein the target selection window includes:

a CT image window configured to display a slice of the CT image data;

a localizer window configured to display an image of at least one lung, the localizer window including a localizer configured to identify a location of the displayed slice relative to the at least one lung; and

a target selection element configured to select the at least one target from the displayed slice of CT image data in response to a user input.

3. The system according to claim **2**, wherein the at least one processor is configured to generate a three-dimensional CT volume from the CT image data selected by the user.

4. The system according to claim **1**, wherein the rotation interface further includes one or more rotation indicators.

5. The system according to claim **4**, wherein the rotation indicators are configured to divide the rotation interface into a plurality of portions which display the amount of rotation of the CT image out of a total rotation amount of three-hundred and sixty degrees.

6. The system according to claim **1**, wherein the rotation interface further includes one or more rotation arrows.

7. The system according to claim **6**, wherein the one or more rotation arrows are configured to display a current rotation location.

8. The system according to claim **1**, wherein the rotation interface further includes a rotation bar and one or more rotation arrows.

9. The system according to claim **8**, wherein the rotation bar is configured to slide within the rotation interface relative to the one or more rotation arrows as the CT image is rotated.

10. The system according to claim **8**, wherein the rotation bar is configured to be aligned with the one or more rotation arrows at an initial rotational orientation of the CT image.

11. The system according to claim **8**, wherein the rotation bar is further configured to appear at an opposite end of the rotation interface after sliding to an opposite end of the rotation interface during rotation of the CT image.

12. The system according to claim **8**, wherein the rotation interface is configured to provide rotation information regarding the amount of rotation of the CT image about an axis relative to the initial rotational orientation of the CT image.

13. A method for planning a pathway through an anatomical luminal network of a patient, the method comprising the steps of:

importing computed tomographic (CT) image data of a patient selected by a user input;

generating a three-dimensional CT volume from the CT image data;

displaying a slice of the three-dimensional CT volume;

defining an initial axis of rotation extending from at least one target to a trachea of the three-dimensional CT volume;

enabling rotation of the three-dimensional CT volume about the initial axis of rotation;

determining whether a waypoint is inside or outside an airway;

redefining the initial axis of rotation as a redefined axis of rotation extending between the at least one target to the waypoint in response to determining that the waypoint is outside an airway of the three-dimensional CT volume;

enabling rotation of the three-dimensional CT volume about the redefined axis of rotation in response to determining that the waypoint is outside an airway of the three-dimensional CT volume; and

displaying an amount of rotation of the three-dimensional CT volume.

14. The method according to claim **13**, wherein displaying an amount rotation of the three-dimensional CT volume further includes:

displaying one or more rotation indicators, which divide a rotation interface into a plurality of portions which display the amount of rotation of the CT volume out of a total rotation amount of three-hundred and sixty degrees.

15. The method according to claim **13**, wherein displaying an amount rotation of the three-dimensional CT volume further includes:

displaying one or more rotation arrows, which depict a current rotation location.

16. The method according to claim **13**, wherein displaying an amount rotation of the three-dimensional CT volume further includes:

displaying one or more rotation arrows and a rotation bar; and

sliding the rotation bar relative to the one or more rotation arrows as the CT volume is rotated.

17. A non-transitory computer-readable storage medium encoded with a program that, when executed by a processor, causes the processor to perform the steps of:

importing computed tomographic (CT) image data of a patient selected by a user input;

generating a three-dimensional CT volume from the CT image data;

displaying a slice of the three-dimensional CT volume;

defining an initial axis of rotation extending from at least one target to a trachea of the three-dimensional CT volume;

enabling rotation of the slice of the three-dimensional CT volume about the initial axis of rotation;

determining whether a waypoint is inside or outside an airway;

redefining the initial axis of rotation as a redefined axis of rotation extending between the at least one target to the waypoint in response to determining that the waypoint is outside an airway of the three-dimensional CT volume; and

enabling rotation of the slice of the three-dimensional CT volume about the redefined axis of rotation in response to determining that the waypoint is outside an airway of the three-dimensional CT volume.

18. The non-transitory computer-readable storage medium according to claim **17**, wherein the program, when executed by the processor, causes the processor to perform the step of:

displaying one or more rotation indicators.

19. The non-transitory computer-readable storage medium according to claim **17**, wherein the program, when executed by the processor, causes the processor to perform the step of:

displaying one or more rotation arrows.

20. The non-transitory computer-readable storage medium according to claim **17**, wherein the program, when executed by the processor, causes the processor to perform the step of:

displaying a rotation bar.

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